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PEDCo-Environmental, Inc., Durham, NC

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A STUDY OF PERSONAL EXPOSURE TO CARBON MONOXIDE IN DENVER, COLORADO

by

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Under EPA Contract 68-02-3755, PEDCo Environmental conducted a study of personal exposure to carbon monoxide (CO) in Denver, Colorado. The target population for the study included all noninstitutionalized, nonsmoking residents of the urbanized portion of the metropolitan area who were between 18 and 70 years of age at the time of the study. A total of 454 study participants were obtained through the use of a screening questionnaire administered to several thousand households in the study area. Each participant was asked to carry a personal exposure monitor (PEM) and an activity diary for two consecutive 24-hour sampling periods and to provide a breath sample at the end of each sampling period. Each participant also completed a detailed background questionnaire. Analyses of approximately 900 person-days of PEM and activity diary data found that personal CO exposures were higher in microenvironments associated with motor vehicles such as parking garages and automobiles. Mean indoor residential exposure was increased 2.59 ppm by gas stove operation, 1.59 ppm by the presence of smokers, and 0.41 ppm by attached garages. Approximately 3 percent of the daily maximum 1-hour exposures exceeded 35 ppm; approximately 11 percent of the daily maximum 8-hour exposures exceeded 9 ppm.

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FOREWORD

Measurement and monitoring research efforts are designed to anticipate potential environmental problems, to support regulatory actions by developing an in-depth understanding of the nature and processes that impact health and the ecology, to provide innovative means of monitoring compliance with regulations and to evaluate the effectiveness of health and environmental protection efforts through the monitoring of long-term trends. The Environmental Monitoring Systems Laboratory, Research Triangle Park, North Carolina, has the responsibility for: assessment of environmental monitoring technology and systems; implementation of agency-wide quality assurance programs for air pollution measurement systems; and supplying technical support to other groups in the Agency including the Office of Air, Noise and Radiation, the Office of Toxic Substances and the Office of Enforcement.

This document is a report of the development and application of personal exposure methodology for carbon monoxide to the residents of Denver, Colorado, during the winter of 1982-83. This report discusses the methodology used in the study and the results of applying this methodology.

Thomas R. Hauser
Director
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Systems Laboratory

ABSTRACT

Under EPA Contract 68-02-3755, PEDCo Environmental conducted a study of personal exposure to carbon monoxide (CO) in Denver, Colorado. The target population for the study included all noninstitutionalized, nonsmoking residents of the urbanized portion of the metropolitan area who were between 18 and 70 years of age at the time of the study. A total of 454 study participants were obtained through the use of a screening questionnaire administered to several thousand households in the study area. Each participant was asked to carry a personal exposure monitor (PEM) and an activity diary for two consecutive 24-hour sampling periods and to provide a breath sample at the end of each sampling period. Each participant also completed a detailed background questionnaire. Analyses of approximately 900 person-days of PEM and activity diary data found that personal CO exposures were higher in microenvironments associated with motor vehicles such as parking garages and automobiles. Mean indoor residential exposure was increased 2.59 ppm by gas stove operation, 1.59 ppm by smokers, and 0.41 ppm by attached garages. The weighted means for daily maximum 1-hour and 8-hour exposures during the study period were 10.3 ppm and 4.9 ppm, respectively. Approximately 3 percent of the daily maximum 1-hour exposures exceeded 35 ppm; approximately 11 percent of the daily maximum 8-hour exposures exceeded 9 ppm. Only one of the 15 fixed-site monitors operating during the study reported daily maximum 1-hour values exceeding 35 ppm. Eleven fixed-site monitors reported daily maximum 8-hour values exceeding 9 ppm. Correlations between CO values recorded simultaneously by PEM's and by fixed-site monitors were generally higher for outdoor personal monitoring locations than for indoor locations; however, correlations were weak for most locations. Diurnal patterns for weekdays, Saturdays, and Sundays were developed for hourly average exposures and composite fixed-site values.

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LIST OF ABBREVIATIONS

ABBREVIATIONS

ANOVA -- analysis of variance
APCD -- Air Pollution Control Division of the Colorado Department of Health
BCL -- Biometrics Consulting Laboratory
BG -- block group (Section 2.1)
BMDP -- package of computer programs for statistical analysis
CALIB-DATA -- computer file containing zero-span data and breath CO measurements (Section 4.10)
CCC -- calibration class code (Section 4.10)
CMIQ -- computer model input questionnaire (Section 3.2)
CMR -- Colorado Market Research
CO -- carbon monoxide
DQC -- data quality code (Section 4.11)
DRCOG -- Denver Regional Council of Governments
EHUS -- ratio of the number of 1980 Census occupied housing units for the sample segment divided by the number of Donnelley listings for the sample segment (Section 2.2)
EPA -- U.S. Environmental Protection Agency
EWA -- enclosed work area
FSU -- first-stage sample unit (Section 2.1)
GE -- General Electric
HOI -- half-open interval (Section 2.2)
HP -- Hewlett Packard
HU -- housing unit (Section 2.1)
LCD -- liquid crystal display
Magus -- Magus Group, Incorporated
NAAQS -- National Ambient Air Quality Standard
n.e.c. -- not elsewhere coded
NEM -- NAAQS Exposure Model (Section 3.2)
PEDCo -- PEDCo Environmental, Incorporated
PEM -- personal exposure monitor
PID -- personal identification number
PROFILE -- computer program used to graphically display personal exposure data (Section 4.12)
RA -- number of residential acres in census tract (Section 5.1)
RDEN -- residential density (Section 5.1)
RES -- number of census tract residents (Section 5.1)
ROM -- read-only memory
RTI -- Research Triangle Institute
SAMPLE-DATA -- computer file containing personal exposure data (Section 4.10)
SAROAD -- Storage and Retrieval of Aerometric Data (EPA data bank)
SHAPE -- Simulation of Human Air Pollution Exposures (Section 3.2)
SSU -- second-stage sampling unit (Section 2.1)
TDEN -- trip density (Section 5.1)
WTI -- number of home-to-work trips per day that terminate in a census tract (Section 5.1)
WTO -- number of home-to-work trips per day that originate in a census tract (Section 5.1)

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SECTION 1

INTRODUCTION

Under EPA Contract 68-02-3755, PEDCo conducted a study of personal exposure to carbon monoxide (CO) in the Denver metropolitan area. The primary objective of this study was to validate a proposed methodology for measuring the distribution of CO exposures in a representative urban sample so that risk to the entire population can be assessed. A total of 454 study participants were obtained through the use of a screening questionnaire administered to several thousand households in the study area. Each participant was asked to carry a personal exposure monitor (PEM) and activity diary for two consecutive 24-hour sampling periods and to provide a breath sample at the end of each sampling period. Each participant also completed a detailed background questionnaire. The questionnaire results and approximately 900 subject-days of CO and activity diary data were analyzed to determine if selected factors significantly affect personal CO exposure. In addition, the exposure of the entire Denver target population was extrapolated from exposures recorded by the study participants. PEDCo also compared CO levels recorded by fixed-site monitors with levels recorded simultaneously by the personal monitors. This study should provide an activity-pattern data base that can be used to improve existing models for estimating CO exposure.

The Research Triangle Institute (RTI) assisted in the study by developing first-stage sampling units, administering telephone screening questionnaires, and tabulating screening results. PEDCo advised RTI on sample stratification, directed all field activities, calibrated and maintained the PEM's, and analyzed the resulting data. The Biometrics Consulting Laboratory (BCL) of the University of North Carolina at Chapel Hill evaluated the sampling weights proposed by RTI and advised PEDCo on sample stratification. Colorado Market Research (CMR) conducted all field activities and assisted PEDCo in validating the resulting data. Field activities began November 1, 1982, and continued through February 28, 1983.

SECTION 2

STUDY DESIGN

This section discusses the general protocol used in selecting subjects for the Denver CO study. It discusses sample stratification in detail and provides a scheme for weighting the data associated with each subject.

2.1 SAMPLE SELECTION PROTOCOL

The target population of the study included all noninstitutionalized, nonsmoking residents of the urbanized portion of the Denver, Colorado, metropolitan area, who were between 18 and 70 years of age at the time of the study. Research Triangle Institute (RTI) developed a two-phase scheme for sampling this population, which is estimated to be 245,000. In the first phase, a two-stage sample of housing units was selected. Data were collected for all individuals residing within these housing units using a brief screening questionnaire. Individuals who exhibited rare characteristics with respect to CO exposure were identified and oversampled in the second phase of sample selection.

The U.S. Bureau of Census has divided the Denver metropolitan area population into 809 block groups (BG's). As indicated in Figure 2-1, RTI aggregated these BG's into 799 first-stage sampling units (FSU's). Each FSU contains a minimum of 40 occupied housing units (HU's), except in those cases where aggregation would combine BG's from two or more census tracts. RTI then selected 100 FSU's with probability proportional to their 1980 population and with replacement. Because one FSU was selected twice, the sample has only 99 distinct FSU's. These 99 FSU's are referred to as "sample segments." RTI obtained a list of all HU's in the sample segments whose names appear on a list prepared by Donnelley Marketing Information Services of Stanford, Connecticut. Because the Donnelley list is based on telephone directories and vehicle ownership records, it tends to exclude certain types of HU's (e.g., a HU without automobile which has no telephone or which has an unlisted number).

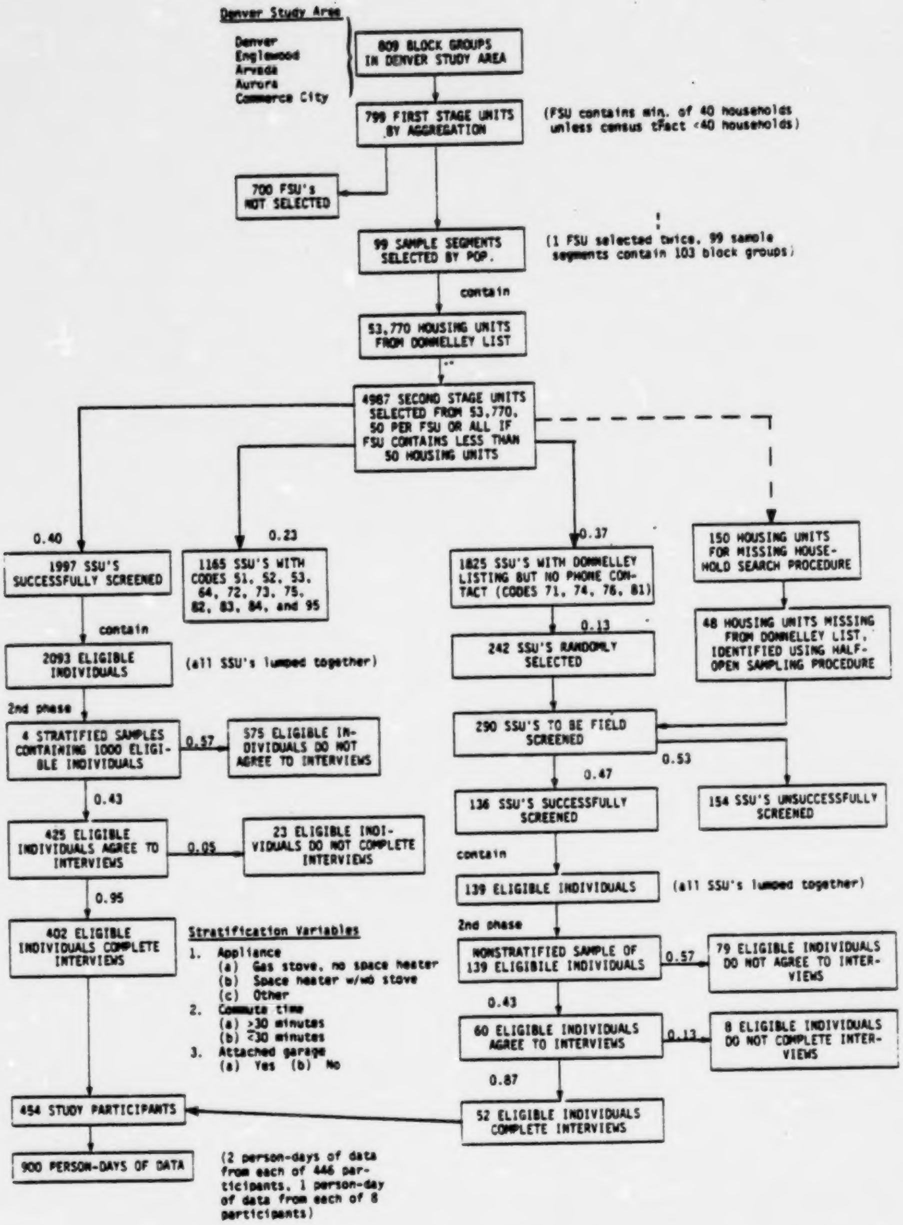

Denver Study Area
Denver
Englewood
Arvada
Aurora
Commerce City
809 BLOCK GROUPS IN DENVER STUDY AREA
799 FIRST STAGE UNITS BY AGGREGATION
(FSU contains min. of 40 households unless census tract <40 households)
700 FSU's NOT SELECTED
99 SAMPLE SEGMENTS SELECTED BY POP.
(1 FSU selected twice, 99 sample segments contain 103 block groups)
contain
53,770 HOUSING UNITS FROM DONNELLEY LIST
4987 SECOND STAGE UNITS SELECTED FROM 53,770, 50 PER FSU OR ALL IF FSU CONTAINS LESS THAN 50 HOUSING UNITS
0.40
1997 SSU'S SUCCESSFULLY SCREENED
0.23
1165 SSU'S WITH CODES 51, 52, 53, 64, 72, 73, 75, 82, 83, 84, and 95
0.37
1825 SSU'S WITH DONNELLEY LISTING BUT NO PHONE CONTACT (CODES 71, 74, 76, 81)
150 HOUSING UNITS FOR MISSING HOUSEHOLD SEARCH PROCEDURE
contain
2093 ELIGIBLE INDIVIDUALS
(all SSU's lumped together)
0.13
242 SSU'S RANDOMLY SELECTED
48 HOUSING UNITS MISSING FROM DONNELLEY LIST, IDENTIFIED USING HALF-OPEN SAMPLING PROCEDURE
2nd phase
4 STRATIFIED SAMPLES CONTAINING 1000 ELIGIBLE INDIVIDUALS
0.57
575 ELIGIBLE INDIVIDUALS DO NOT AGREE TO INTERVIEWS
290 SSU'S TO BE FIELD SCREENED
0.53
0.47
0.43
136 SSU'S SUCCESSFULLY SCREENED
154 SSU'S UNSUCCESSFULLY SCREENED
425 ELIGIBLE INDIVIDUALS AGREE TO INTERVIEWS
0.05
23 ELIGIBLE INDIVIDUALS DO NOT COMPLETE INTERVIEWS
contain
139 ELIGIBLE INDIVIDUALS
(all SSU's lumped together)
0.95
402 ELIGIBLE INDIVIDUALS COMPLETE INTERVIEWS
Stratification Variables
1. Appliance
(a) Gas stove, no space heater
(b) Space heater w/wo stove
(c) Other
2. Commute time
(a) ≥30 minutes
(b) ≤30 minutes
3. Attached garage
(a) Yes (b) No
2nd phase
NONSTRATIFIED SAMPLE OF 139 ELIGIBILE INDIVIDUALS
0.57
79 ELIGIBLE INDIVIDUALS DO NOT AGREE TO INTERVIEWS
0.43
60 ELIGIBLE INDIVIDUALS AGREE TO INTERVIEWS
0.13
8 ELIGIBLE INDIVIDUALS DO NOT COMPLETE INTERVIEWS
0.87
454 STUDY PARTICIPANTS
52 ELIGIBLE INDIVIDUALS COMPLETE INTERVIEWS
900 PERSON-DAYS OF DATA
(2 person-days of data from each of 446 participants, 1 person-day of data from each of 8 participants)

Figure 2-1. Sample selection protocol.

RTI attempted to randomly select 50 HU listings from each sample segment. If a sample segment contained less than 50 listings, all listings were selected. This procedure yielded 4987 second-stage sampling units (SSU's). Of these, 1997 SSU's were successfully screened by telephone, 1165 SSU's fell into Category A, and 1825 fell into Category B (Table 2-1). Category A includes refusals and unreliable respondents; Category B includes Donnelley listings for which the telephone number is incorrect or nonexistent. Names of individuals residing in the successfully screened HU's were lumped together. Removal of smokers and persons under 18 and over 70 yielded a list of 2093 eligible individuals. Based on recommendations from PEDCo and BCL, RTI initially selected three stratified samples containing a total of 703 eligible individuals. The primary sample contained 595 eligible individuals. Two supplementary samples each contained 54 eligible individuals. A third supplementary sample containing 297 eligible individuals was selected near the end of the study when it became evident that more than 703 potential subjects were needed to yield the desired number of study participants. Of the 1000 eligible individuals in the primary and three supplementary samples, 425 agreed to be interviewed. Of these, 402 successfully completed the interviews and participated in the study.

TABLE 2-1. RESULT CODES FOR TELEPHONE SCREENING[1]

Code	Category	Interpretation
01	-	Completed interview
51	A	Refusal or breakoff, conversion attempt failed
52	A	Refusal or breakoff, not reached for conversion attempt
53	A	An eligible housing unit was contacted, but circumstances prevented a screening interview
64	A	Breakoff after Question 7
71[a]	B	Nonworking number
72	A	Nonresidential number
73	A	Entire household moving
74[a]	B	Address doesn't match Donnelley listing
75	A	No reliable respondent (3 attempts)
76[a]	B	No phone number
81[a]	B	Branching, complete silence, fast-busy, or other problem confirmed by an operator
82	A	Ring-no-answer (6 attempts)
83	A	Answering machine (6 attempts)
84	A	Final busy (10 attempts)
95	A	Other (both eligible and ineligible cases)

[a] Result codes for Donnelley listings not covered by the initial telephone screening.

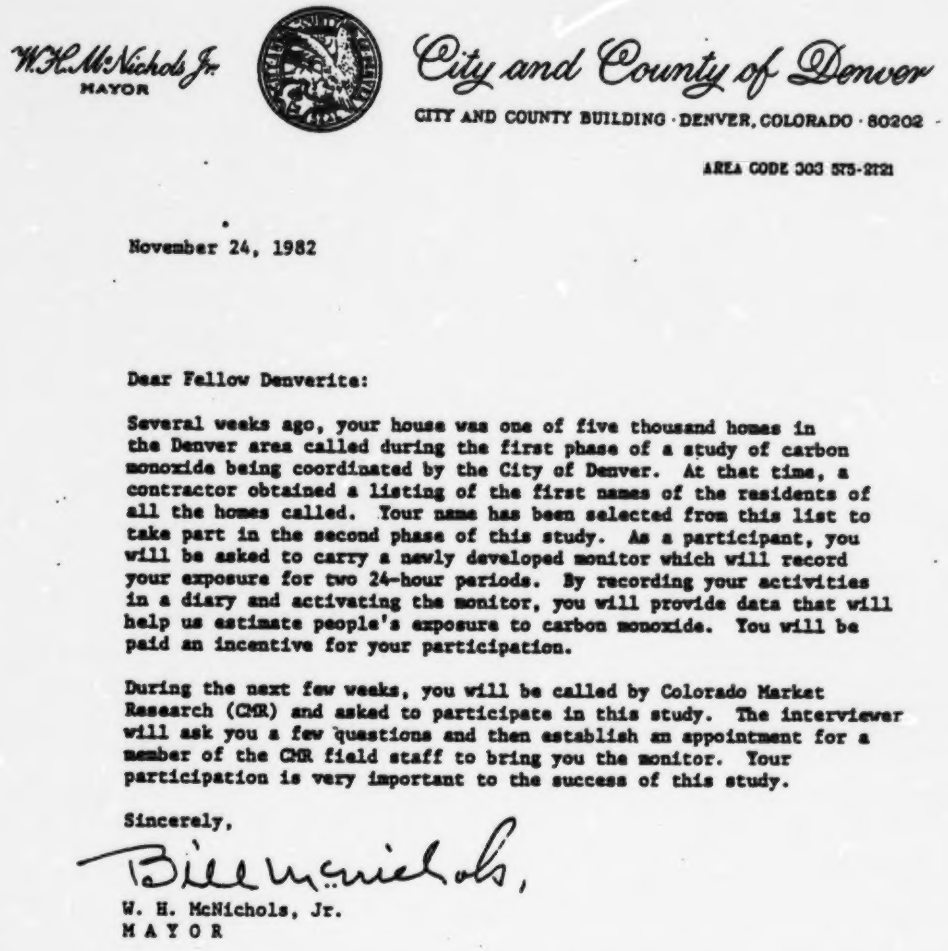
The total number of participants was 454. The remaining 52 participants were selected as follows. A random subsample of 242 HU's was selected from the 1825 SSU's in Category B. These 242 HU's were combined with 48 HU's identified as missing from the Donnelley list by means of a half-open interval (HOI) sampling technique (Section 2.2). PEDCo then attempted to screen these 290 (i.e., 242 + 48) HU's in the field; 142 were screened successfully. These HU's yielded 139 eligible individuals, all of which were selected to participate in the study. Of these eligible individuals, 60 agreed to be interviewed and 52 yielded successful interviews. These 52 individuals combined with the 402 individuals described above yielded a final sample containing 454 study participants.

The original sample selection protocol was designed to yield 500 study participants. The reduced sample size resulted from a higher than expected refusal rate and unexpected equipment problems early in the study. To increase participation, the Mayor of Denver mailed a letter (Figure 2-2) to most members of the primary sample and the first two supplementary samples. In addition, an incentive of $11.00 was paid to each person who participated in the study.

2.2 STUDY AREA HOUSING UNITS NOT ON DONNELLEY LIST

To identify HU's not on the Donnelley list, a subsample of 150 HU's was selected in two stages. First, a subsample of 15 sample segments was selected. Then a subsample of ten Donnelley listings was selected by simple random sampling without replacement from each of these sample segments. The sample segments were selected as a stratified simple random sample without replacement with strata as defined in Table 2-2. This stratification was designed to guarantee that some of the missed HU sample would fall within segments for which the number of 1980 Census occupied housing units was at least 50 percent greater than the number of Donnelley listings.

Each of the 150 HU's became the start point for a HOI sampling procedure. Nearby HU's were surveyed according to a count and list procedure developed by PEDCo (Section 4.1.2). When another HU on the Donnelley list was identified, the number of non-Donnelley HU's between this HU and the start point was recorded. An attempt was made to administer the field screening questionnaire to each of these non-Donnelley HU's so that members of these households



W.H. McNichols Jr.
MAYOR

City and County of Denver
CITY AND COUNTY BUILDING · DENVER, COLORADO · 80202

AREA CODE 303 575-2721

November 24, 1982

Dear Fellow Denverite:

Several weeks ago, your house was one of five thousand homes in the Denver area called during the first phase of a study of carbon monoxide being coordinated by the City of Denver. At that time, a contractor obtained a listing of the first names of the residents of all the homes called. Your name has been selected from this list to take part in the second phase of this study. As a participant, you will be asked to carry a newly developed monitor which will record your exposure for two 24-hour periods. By recording your activities in a diary and activating the monitor, you will provide data that will help us estimate people's exposure to carbon monoxide. You will be paid an incentive for your participation.

During the next few weeks, you will be called by Colorado Market Research (CMR) and asked to participate in this study. The interviewer will ask you a few questions and then establish an appointment for a member of the CMR field staff to bring you the monitor. Your participation is very important to the success of this study.

Sincerely,

Bill McNichols,

W. H. McNichols, Jr.
MAYOR

Figure 2-2. Letter from Mayor of Denver to potential study participants.

TABLE 2-2. STRATIFICATION OF SAMPLE SEGMENTS FOR THE MISSED HU SAMPLE[1]

Stratum number	Stratum definition	Total segments	Selected segments	Sampling weight, $W_4(i)$
1	$0 < \text{EHUS}^a \leq 1.5$	92	13	92/13
2	$\text{EHUS} > 1.5$	7	2	7/2

[a] EHUS is defined to be the ratio of the number of 1980 Census occupied housing units for the sample segment divided by the number of Donnelley listings for the sample segment.

could be included in the study. Section 6.2 summarizes the results of the HOI sampling activities.

2.3 SAMPLE STRATIFICATION

As indicated above, 1997 SSU's were successfully screened by telephone. These SSU's yielded 2093 eligible individuals. Table 2-3 presents tabulations of selected characteristics of these individuals as indicated by the screening questionnaire responses. Existence of smoker(s) in the household was assumed to be a relatively insignificant exposure factor and was not considered in sample stratification. The "space heater, no gas stove" and "gas stove + space heater" groups were combined to form a single group, "space heater." Cross-tabulation yielded 12 classes (Table 2-4) into which the eligible individuals could be divided. Three classes (7,8,9) each contained less than 23 eligible individuals. These three classes were combined with Class 10 to yield the nine strata listed in Table 2-5. Note that the allocation of the 1000 individuals in the sample is not proportional. Strata that would yield less than 69 individuals under proportional sampling were over-sampled to ensure a sufficient number of individuals for statistical analysis. Under this allocation scheme, each stratum yielded at least 43 individuals. Table 2-6 lists the number of eligible individuals selected from each stratum for each of the four stratified samples.

2.4 SAMPLE WEIGHTS

The subjects selected for the Denver CO study do not represent a simple random sample of the Denver metropolitan population. In extrapolating the

TABLE 2-3. TABULATION OF SELECTED CHARACTERISTICS OF ELIGIBLE INDIVIDUALS AS INDICATED BY SCREENING QUESTIONNAIRE RESPONSES

Characteristic	Group	Freq.	Percent
Commute time	< 30 minutes	1528	73.0
	≥ 30 minutes	565	27.0
Unvented appliance	Gas stove, no space heater	524	25.0
	Space heater, no gas stove	101	4.8
	Gas stove + space heater	21	1.0
	Other	1447	69.1
Smoker in household	Yes	535	25.6
	No	1558	74.4
Attached garage	Yes	869	41.5
	No	1224	58.5

TABLE 2-4. CROSS-TABULATION OF SELECTED CHARACTERISTICS IN 2093 ELIGIBLE INDIVIDUALS

Class	Commute time	Unvented appliance	Attached garage	Freq.	Percent
1	< 30 minutes	Space heater	Yes	48	2.3
2			No	43	2.1
3		Gas stove, no space heater	Yes	70	3.3
4			No	342	16.3
5		Other	Yes	529	25.3
6			No	577	27.6
7	≥ 30 minutes	Space heater	Yes	22[a]	1.1
8			No	9[a]	0.4
9		Gas stove, no space heater	Yes	18[a]	0.9
10			No	94	4.5
11		Other	Yes	182	8.7
12			No	159	7.6

[a] Class containing less than 23 eligible individuals.

TABLE 2-5. ALLOCATION OF ELIGIBLE INDIVIDUALS TO COMBINED SAMPLE

Stratum	Commute time	Unvented appliance	Attached garage	Sample allocation	
				Proportional	Proposed
1	< 30 minutes	Space heater	Yes	23	48
2			No	21	43
3		Gas stove, no space heater	Yes	33	56
4			No	163	148
5		Other	Yes	253	229
6			No	276	250
7	≥ 30 minutes	Space heater or gas stove	-	68	74
8		Other	Yes	87	78
9			No	76	74
			Total	1000	1000

TABLE 2-6. ALLOCATION OF ELIGIBLE INDIVIDUALS TO PRIMARY AND SUPPLEMENTARY SAMPLES

Stratum	Commute time	Unvented appliance	Attached garage	Sample allocation[a]			
				P	S1	S2	S3
1	< 30 minutes	Space heater	Yes	29	3	2	14
2			No	25	2	3	13
3		Gas stove, no space heater	Yes	33	3	3	17
4			No	89	7	8	44
5		Other	Yes	136	13	12	68
6			No	149	14	13	74
7	≥ 30 minutes	Space heater or gas stove	-	44	4	4	22
8		Other	Yes	46	4	5	23
9			No	44	4	4	22
			Total	595	54	54	297

[a] P = primary, S1 = first supplementary, S2 = second supplementary, S3 = third supplementary.

exposures of the subjects to the larger population, the data associated with each subject must be weighted according to the probability of selecting the subject from the target population. This section discusses the methods used to determine these weights, including special weights proposed by PEDCo to account for noncoverage of sampling units, refusals, instrument malfunctions, and other nonresponse problems.

2.4.1 Donnelley Listings Initially Screened by Telephone

Let S(i) equal the number of occupied housing units in the ith sample segment according to the 1980 census. The first-stage sampling weight component for the ith sample segment is

$$W_1(i) = [\frac{1}{100} \sum_{j=1}^{m} S(j)]/S(i) * n_i \tag{2-1}$$

where m = 799 (i.e., m equals the number of FSU's) and n_i is the number of times sample segment i is selected. Now let D(i) equal the number of Donnelley listings received for the ith sample segment. If M(i) equals the number of Donnelley listings selected for the ith sample segment, then the second-stage sampling weight component is

$$W_2(i) = D(i)/M(i). \tag{2-2}$$

The quantity

$$s_1(i) = W_1(i) * W_2(i) \tag{2-3}$$

is thus the sampling weight associated with each Donnelley listing initially screened by telephone.

2.4.2 Donnelley Listings Not Initially Screened by Telephone

As shown in Figure 2-1, a total of 1825 sample Donnelley listings were not covered by the initial telephone screening for Denver. A simple random sample of n_2 = 242 of these listings was selected without replacement. An attempt was made to field screen each listing in this subsample. Because a simple random sample was selected in each case, the sampling weight component is

$$W_3 = 1825/242 = 7.54 . \tag{2-4}$$

The sampling weight associated with each Donnelley listing from the ith sample segment in the subsample of n_2 listings can be expressed as

$$s_2(i) = W_1(i) * W_2(i) * W_3. \tag{2-5}$$

2.4.3 Non-Donnelley Housing Units

To check for missed HU's, a subsample of 150 HU's were selected in two stages. First, a subsample of 15 sample segments was selected. Then a subsample of 10 Donnelley listings was selected by simple random sampling without replacment from each of these sample segments. The sample segments were selected as a stratified simple random sample without replacement with strata as defined in Table 2-2. The sampling weight component associated with the selection of sample segments for the missed HU sample is the ratio of the number of FSU's belonging to a stratum divided by the number of FSU's selected from the stratum; this weight is denoted by $W_4(i)$ in Table 2-2. Similarly, the weight component for the subsample of 10 listings from the ith selected sample segment is

$$W_5(i) = M(i)/10, \tag{2-6}$$

where M(i) is the total number of Donnelley listings available for the ith sample segment. Hence, the final sampling weight for each of the listings selected into the missed HU sample is

$$s_3(i) = W_1(i) * W_2(i) * W_4(i) * W_5(i). \tag{2-7}$$

This sampling weight is associated with all missed HU's that enter the sample through the ith selected sample segment.

2.4.4 Adjustments for Nonresponse to Screening Instrument

The results of an attempt to administer the screening questionnaire to the jth HU of the ith sample segment were classified according to three indicators:

$$\text{RESP}(i,j) = \begin{matrix} 1 \text{ if the unit responded} \\ 0 \text{ otherwise} \end{matrix}$$

$$\text{ELGKWN}(i,j) = \begin{matrix} 1 \text{ if the eligibility status was determined} \\ 0 \text{ otherwise} \end{matrix}$$

$$\text{ELIG}(i,j) = \begin{matrix} 1 \text{ if the unit was determined to be eligible} \\ 0 \text{ otherwise} \end{matrix}$$

If two or more sample segments with similar characteristics are grouped together in a weighting class, an estimate of the proportion of eligible HU's in the hth weighting class can be computed as

$$\mathrm{ELGPROP}(h) = \frac{\Sigma \mathrm{WSCR}(i,j) * \mathrm{ELIG}(i,j)}{\Sigma \mathrm{WSCR}(i,j) * \mathrm{ELGKWN}(i,j)} \qquad (2\text{-}8)$$

where

$$\mathrm{WSCR}(i,j) = W_1(i) * W_2(i) \qquad (2\text{-}9)$$

for HU's that enter the sample through the initial telephone screening,

$$\mathrm{WSCR}(i,j) = W_1(i) * W_2(i) * W_3 \qquad (2\text{-}10)$$

for HU's that enter the sample through the field screening of Donnelley listings with no phone contact, and

$$\mathrm{WSCR}(i,j) = W_1(i) * W_2(i) * W_4(i) * W_5(i) \qquad (2\text{-}11)$$

for HU's that enter the sample through the missed HU survey. In Equation 2-8, j identifies a particular HU in the ith sample segment and each summation extends over all HU's in weighting class h.

The adjustment factor for HU nonresponse within the hth weighting class is computed as

$$\mathrm{KHU}(h) = \frac{\Sigma \mathrm{WSCR}(i,j) * \mathrm{ELGPROP}(h)}{\Sigma \mathrm{WSCR}(i,j) * \mathrm{RESP}(i,j)} \qquad (2\text{-}12)$$

where each summation again extends over all HU's in the hth weighting class. The numerator of this ratio estimates the number of eligible HU's that belong to weighting class h. This adjustment factor is used to produce the adjusted weight

$$\mathrm{WSCRADJ}(i,j) = \mathrm{WSCR}(i,j) * \mathrm{KHU}(h) * \mathrm{RESP}(i,j), \qquad (2\text{-}13)$$

for each housing unit that belongs to the hth weighting class. The sum of the adjusted weights, WSCRADJ, over all housing units in the hth weighting class provides an estimate of the number of eligible housing units in the weighting class.[1]

A primary consideration in RTI's methodology for defining weighting classes was that response rates and/or response values be more homogeneous within classes than between classes. For HU's obtained from the initial telephone screening, RTI defined 33 weighting classes. Each class contains three sample segments located near to one another. For HU's obtained through the field screening of Donnelley listings with no phone contact, RTI defined two weighting classes. One class contains 53 sample segments more likely to be located in the center-city area; the other contains 46 sample segments more likely to be located in suburban areas. All HU's obtained through the missed HU survey were assigned to the same weighting class. Each screened HU is thus associated with one of 36 (i.e., 33 + 2 + 1) weighting classes.

2.4.5 Person-Level Components

As indicated in Figure 2-1 and Table 2-5, a stratified sample of 1000 eligible individuals was selected from 2093 eligible individuals identified through the initial screening of Donnelley listings by telephone. The person-level weight component of a selected individual belonging to stratum k is

$$W_8(k) = N(k)/n(k), \tag{2-14}$$

where N(k) is the number of screened eligible individuals from stratum k and n(k) is the ultimate sample size from stratum k.

Strata were not defined for the eligible individuals identified through the field screening of Donnelley listings with no telephone contact or through the missed HU survey. Because all of these eligible individuals were selected, the person-level component for each is unity.

2.4.6 Adjustments for Missing Data

As indicated in Figure 2-1, 1139 (i.e., 1000 + 139) eligible individuals were asked to participate in the study. If all had participated and no data had been lost, the study would have yielded 2278 person-days of data. This total was not obtained because of refusals to participate, sickness, equipment malfunctions, incomplete diaries, and other nonresponse problems. Assuming these nonresponse factors occurred randomly within each stratum of eligible individuals, the adjustment factor for missing data in stratum k can be calculated as

$$W_9(k) = \frac{2 * n(k)}{m(k)} \tag{2-15}$$

where m(k) is the number of valid person-days of data that were obtained from participants of stratum k and 2 * n(k) is the maximum number of possible person-days of data. Values of $W_9(k)$ are specific to the data item of interest.

2.4.7 Adjusted Overall Sampling Weights

The sampling weight assigned to a valid person-day of data provided by a member of stratum k belonging to HU j in sample segment i in weighting class h is

$$W = WSCR(i,j) * KHU(h) * RESP(i,j) * W_8(k) * W_9(k) . \qquad (2\text{-}16)$$

For individuals identified by the initial telephone screening, the WSCR(i,j) is given by Equation 2-9 and W_8 is given by Equation 2-14. For individuals identified by field screening of Donnelley listings with no previous telephone contact, WSCR(i,j) is given by Equation 2-10 and W_8 = 1.0. For individuals identified by the missed HU survey, WSCR(i,j) is given by Equation 2-11 and W_8 = 1.0.

2.5 REFERENCE

1. Whitmore, R., S. Jones, and M. Rosenzweig. Final Sampling Report for the Study of Personal CO Exposure. Report No. RTI/2390/02-01F. Research Triangle Institute. Research Triangle Park, North Carolina. September 1983.

SECTION 3

DATA COLLECTION INSTRUMENTS

This section discusses the various data collection instruments used in the Denver CO study. These include three questionnaires providing background data on subjects and their families, the fixed-site and personal exposure monitors, the activity diary, the field data sheet, and the breath sample bag. The procedures used to collect data are discussed in Section 4.

3.1 FIELD SCREENING QUESTIONNAIRE

Appendix A contains the field screening questionnaire and instructions for administering it. The questions on the field screening questionnaire are identical to those on the screening questionnaire that RTI administered by telephone to 1997 second-stage sampling units (Section 2.1). The field screening questionnaire requests the name of each household member, relationship to head of household, sex, age, smoking status, occupation, and typical commuting time. It also asks if the household has an attached garage or any of seven indoor CO sources. Colorado Market Research (CMR) administered the field screening questionnaire to households with Donnelley listings that could not be contacted by telephone and to households identified as missing from the Donnelley list. Procedures used in administering the field screening questionnaire are discussed in Section 4.1.

3.2 COMPUTER MODEL INPUT QUESTIONNAIRE

Appendix B contains the computer model input questionnaire (CMIQ). An attempt was made to administer the CMIQ to eqch person identified as a potential study participant. Part A of the CMIQ requests detailed data about the commuting habits of the respondent's household and asks if any member of the household is employed in one of nine occupational categories associated with high CO exposure. These data were collected for use in SHAPE, a population exposure model developed by Wayne Ott,[1] and NEM, a population exposure model developed by the Strategies and Air Standards Division of the U.S. Environmental Protection Agency (EPA).[2] Part B of the CMIQ verifies the respondent's address and attempts to set up an appointment for the first visit by an interviewer.

3.3 STUDY QUESTIONNAIRE

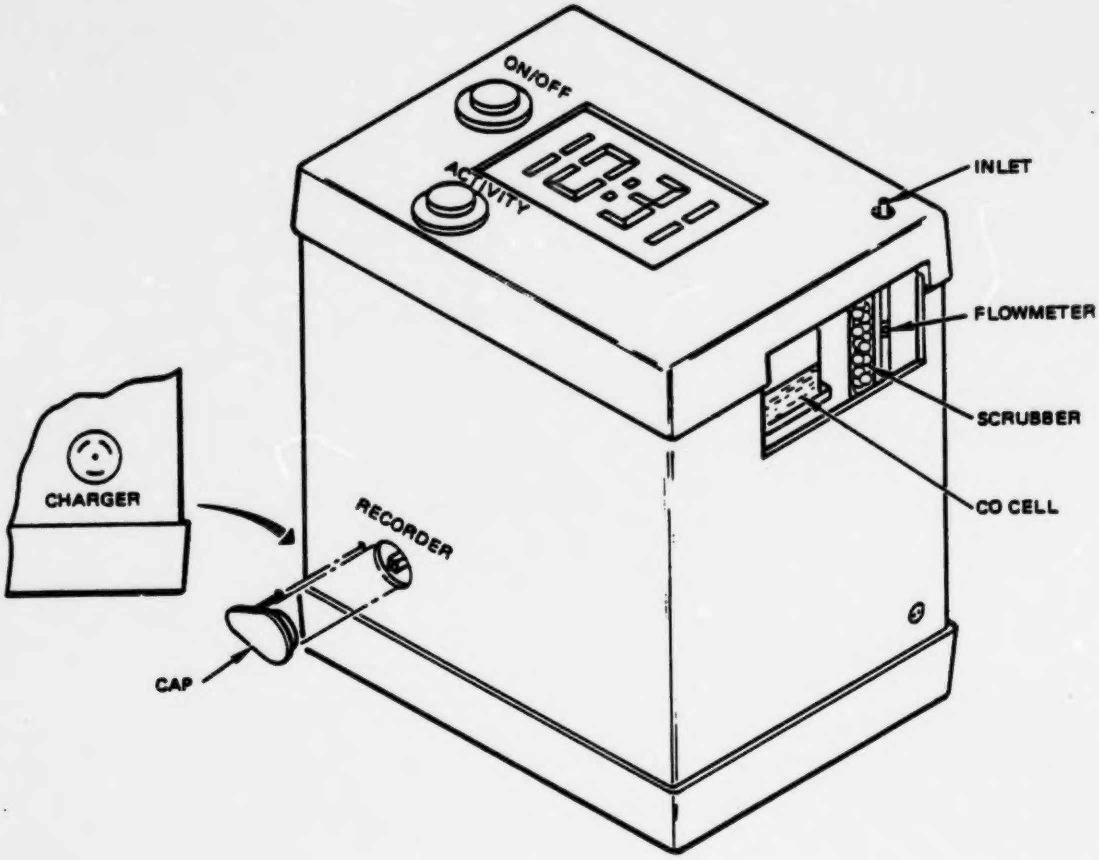
Appendix C contains the study questionnaire. This questionnaire was administered to all persons who actually participated in the study. It includes detailed questions about the subject's home environment, work environment, commuting habits, occupation, leisure-time activities, and shopping habits. The study questionnaire also asks for age, sex, and education data. A section for field use (page 12) provides information concerning structure type and building material of residence. During the latter half of the study, interviewers asked each subject if participation in the study altered his/her normal activity pattern. The responses were recorded in the comments section on page 12 of the study questionnaire.

3.4 PERSONAL EXPOSURE MONITOR

The PEM is a modified General Electric (GE) Carbon Monoxide Detector, Model 15EC53003, mated with a modified Magus DL-1 Data Logger and mounted in a compact, tamperproof casing. The PEM records the time and a CO concentration value every time the "activity button" on the top of the instrument is pushed and every hour on the hour. In both cases, the CO value is the absolute value of the integrated average CO concentration since the last recorded value. The PEM is capable of operating continuously for 24 hours and logging up to 113 data points.

Figure 3-1 shows the PEM controls, liquid crystal display (LCD), and access points with cover in place. The activity button is located under a flexible black cover on the left side of the instrument. The on/off pushbutton switch controls power from the battery pack to the pump. Power is constantly applied to the CO sensor cell to maintain its stability regardless of the position of the on/off switch. The on/off switch is located under a hard plastic cap and is not accessible to study participants.

An ambient air sample is drawn into the detector through a potassium permanganate filter by an integral sample air pump. The sample is discharged


ON/OFF
ACTIVITY
INLET
FLOWMETER
SCRUBBER
CO CELL
CHARGER
RECORDER
CAP

(SCALE 1:2 APPROXIMATELY)

Figure 3-1. Personal exposure monitor.

to the CO sensor cell, the CO is oxidized, and an electrical signal proportional to the CO level is produced. The air sample is then exhausted through the flow indicator inside the case. The filter provides selectivity of the detector to CO by removing most interfering gases. Hydrogen, ethylene, and acetylene are potential interferents that may not be completely removed by the filter.

Under normal operating conditions, the LCD displays the time. When the activity button is pressed, the LCD momentarily displays the word GULP to indicate that the instrument has received the signal to log data.

Procedures for calibrating and programming the PEM are discussed in Section 4.5. Table 3-1 lists the general specifications of the instrument.

3.5 ACTIVITY DIARY

An activity diary was provided to each subject for each of the two 24-hour periods during which the subject carried a PEM. Appendix E contains facsimiles of selected pages from the diary. The actual diary is 5.5 inches by 8.5 inches in size.

The cover of the diary contains spaces for filling in the personal identification number (PID) of the subject, the monitor identification number, the date and time of first diary entry, and the date and time of last diary entry. Inside the cover are spaces for entering the interviewer's name and telephone number. Also listed are the telephone numbers of representatives of Colorado Market Research and PEDCo Environmental who could be called if the subject had questions or problems.

The next two pages list instructions for completing the activity diary. Note that the subject was not required to fill out a diary page when starting an activity that he or she expected to last less than 5 minutes unless that activity required the subject to enter an enclosed garage or parking structure.

Following the instructions are six examples of properly completed activity pages. In the first example, the subject presses the activity button on the PEM at 7:47 as he begins walking from home to a bus stop. Because he is "in transit," he circles 1 under LOCATION; ignores ADDRESS; records his start address, his end address, and mode of travel under ONLY IF IN TRANSIT; ignores ONLY IF INDOORS; and notes that no smokers were present under ALL LOCATIONS. In the second example, the subject pushes the PEM button at 8:01 as he begins

TABLE 3-1. GENERAL SPECIFICATIONS OF PERSONAL EXPOSURE MONITOR

Dimensions: 6.3 x 5.1 x 3.3 inches

Weight: 2.1 pounds (0.95 kg)

Nominal operating time (fully charged batteries):
  CO detector: 24 hours
  Data logger: 3 days

Battery packs:
  CO detector: Four (4) Ni/Cd AA cells
  Data logger: Six (6) Ni/Cd AA cells

Battery charger: Dual outputs via DIN connector

Charging time: 14 hours minimum

Battery discharger (optional): Dual outputs via DIN connector

Discharging time: 2 to 5 hours

Lower detectable limit: 1 ppm (LCD display reads to nearest whole number, 0 may be + or -)

Warm-up time: 15 seconds (after 14-hour battery charge)

Response time: Within 2 minutes to 90 percent

Attitude: Within 45 degrees of vertical

Storage temperature range: 1° to 50°C (34° to 122°F)

working in a machine shop, writes "factory" under other indoor location in the LOCATION section, records the factory address under LOCATION, ignores the ONLY IF IN TRANSIT section, and makes the appropriate notations in the ONLY IF INDOORS and ALL LOCATIONS sections.

Following the examples are 64 blank pages for recording activities. The subject was provided with additional pages if he or she indicated they might be required.

3.6 FIELD DATA SHEET

Appendix F contains the field data sheet used for recording PEM CO values and coded activity diary data. On the first page are spaces for recording CO monitor number, PID number, data concerning the persons who read and verified the data, and corresponding calendar dates. The four digit 24-hour clock times and corresponding CO concentrations recorded by the PEM are entered in sequence under "Time" and "CO conc., ppm," respectively. Entries under ACTIVITY in the diary are coded according to Table 3-2 and recorded under "A." LOCATION entries are recorded under "B." Table 3-3 is used for coding diary entries under "other indoor location" and "other outdoor location." Otherwise 01, 02, 03, 04, 05, 07, or 08 is recorded. Table 3-4 is used for coding address entries under ADDRESS and ONLY IF IN TRANSIT. These codes are recorded under "C," "D1," and "D2" as required. The codes 01, 02, and 03 are recorded under "E1," "E2," and "F" according to the diary entries under ONLY IF INDOORS and ALL LOCATIONS.

The PEM automatically records time and concentration values every hour. In these cases, code 19 is entered under "A" and no codes are entered under B, C, D1, D2, D3, E1, E2, and F. Section 4.10.2 describes how code 19 entries were processed.

3.7 BREATH SAMPLE BAG

Breath samples were taken by having each subject blow through a disposable mouth piece into a 600 ml plastic carboxyhemoglobin bag. The bag was sealed using an open-sided pinchcock. To measure the CO concentration of the breath sample, a prefilter containing potassium permanganate and activated carbon was inserted between the mouthpiece and a General Electric CO-3 portable CO monitor. Figure 3-2 shows the various parts of this sampling train. The procedure used to obtain the breath sample is described in Section 4.4. The procedure used to measure the CO concentration in the breath sample is described in Section 4.6.

3.8 FIXED-SITE MONITORS

Table 3-5 lists the 15 fixed-site monitors that were operating in Denver during the period of the study. Figure 3-3 shows the locations of these 15 monitors. Nine monitors were temporary and were discontinued at the conclusion of the study. All of the monitors reported hourly average CO data and operated continuously.

TABLE 3-2. ACTIVITY CLASSIFICATION SYSTEM

Travel	
01	All travel
Work	
02	Work (income-related) and study
Household activities	
03	Cooking
04	Laundry
05	Other indoor chores and child care
06	Yard work and other outdoor activities
Errands and shopping	
07	Errands and shopping
Personal needs	
08	Eating
09	Sleeping
10	Other personal needs
Social, political, or religious activities	
11	Social, political, or religious activites
Leisure activities	
12	Cafe or pub
13	Walking, bicycling, or jogging (not in transit)
14	Other leisure activities
Additional codes	
15	Uncertain of applicable code
16	No entry in diary
17	Interview
18	Final entry
19	Autolog value (i.e., hourly value automatically logged by PEM)
20	Begin breath sample
21	End breath sample

TABLE 3-3. SUPPLEMENTARY LOCATION AND TRANSIT CODES

Other indoor location

50	Not specified
51	Residential garage
52	Public garage
53	Manufacturing facility
54	Service station or motor vehicle repair facility
55	Other repair shop
56	Auditorium, sports arena, concert hall, etc.
57	Church
58	Shopping mall
59	Health care facility
60	School
61	Other public building (library, courtroom, etc.)
62	Other indoor location

Other outdoor location

70	Not specified
71	Residential garage or carport
72	Public garage
73	Parking lot
74	Service station or motor vehicle repair facility
75	Construction site
76	Residential grounds
77	School grounds
78	Sports arena, amphitheater, etc.
79	Park or golf course
80	Other outdoor location

Other transit mode

90	Not specified
91	Jogging
92	Bicycle
93	Motorcycle
94	Airplane
95	Motorized boat
96	Nonmotorized boat
97	Other transit mode

TABLE 3-4. CENSUS TRACT CODES

Inside Denver SMSA: enter 5-digit code

Example	Code
6	00600
7.01	00701
10	01000
11.01	01101
100	10000
102.03	10203

Outside Denver SMSA but within Colorado

1. Town: enter first 5 letters of town name
2. Outside town: enter first 5 letters of county name

Outside Colorado

1. Town: enter 2-letter state abbrevation followed by $\log_{10}$ (population) rounded to 2 decimal places

Example	Code
Farmington, NM (pop. 32,700)*	NM451

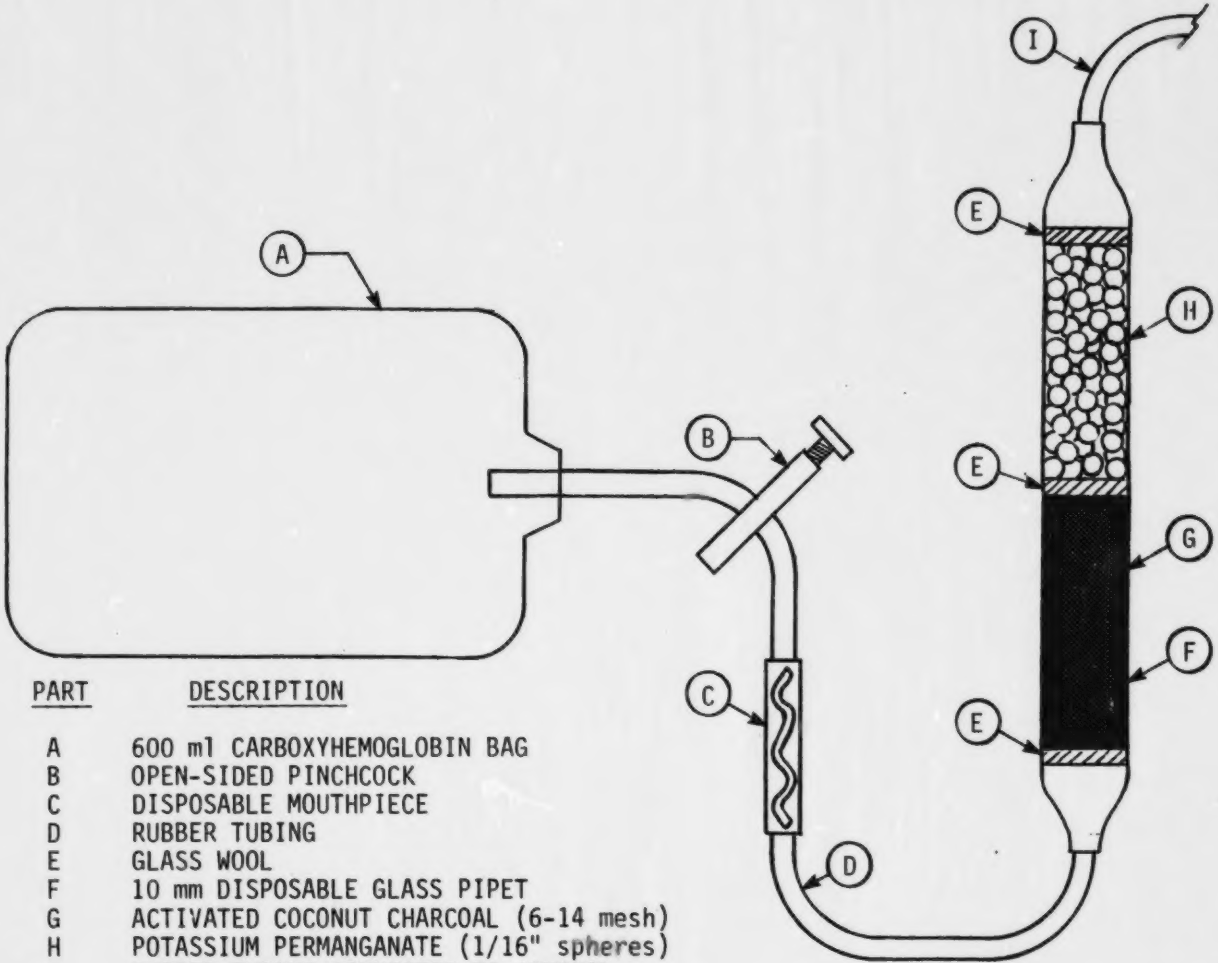
2. Outside town: enter 2-letter state abbreviation followed by XXX

Example	Code
Carson National Forest, NM	NMXXX

Location unknown: enter 99999

---

*Note: $\log_{10}$ (32,700) = 4.51.



PART	DESCRIPTION
A	600 ml CARBOXYHEMOGLOBIN BAG
B	OPEN-SIDED PINCHCOCK
C	DISPOSABLE MOUTHPIECE
D	RUBBER TUBING
E	GLASS WOOL
F	10 mm DISPOSABLE GLASS PIPET
G	ACTIVATED COCONUT CHARCOAL (6-14 mesh)
H	POTASSIUM PERMANGANATE (1/16" spheres)
I	RUBBER TUBING CONNECTED TO GENERAL ELECTRIC CO-3 MONITOR

Figure 3-2. Sampling train for measuring CO concentration in breath sample bag.

TABLE 3-5. FIXED-SITE MONITORS OPERATING IN THE DENVER METROPOLITAN AREA DURING STUDY

Map code	District or town	Address	SAROAD code	Building	Land use	Census tract	RDEN	TDEN	1981 violations
A	Denver	2105 Broadway	060580002F01	Special	Central business, high traffic	a	b	c	33
B	Denver	2325 Irving	060580014F01	Special	Residential	5.02	18.35	5.91	16
C	Denver	14th & Albion	060580013F01	Special	Strip commercial, high traffic	43.01	23.34	35.27	d
D	Denver	208 Grant St.	062080821F05	School	Downtown residential	28.02	30.77	19.03	e
E	Denver	1821 S. Yates	062080822F05	School	Residential, near commercial	46.01	11.79	5.72	e
F	Denver	3635 Quivas St.	062080820F05	School	Residential, near expressway	11.02	27.95	7.90	e
G	Denver	3509 S. Glencoe	062080823F05	School	Residential, on suburban artery	40.04	8.51	5.53	e
H	Greenwood Village	6060 South Quebec	062080825F05	Trailer	Office, light business	67.02	7.97	2.78	e
I	Denver	3620 Franklin St.	062080818F05	School	Residential	36.01	26.75	5.06	e
J	Denver	Speer & Lawrence	062080819F05	School	Campus near high traffic	19.00	67.64	8.56	e
K	Aurora	50 S. Peoria	060140002F01	Special	Suburban golf course	77.02	8.51	4.96	0
L	Arvada	5701 Garrison	060120002F01	Trailer	Residential near shopping district	103.08	8.89	6.19	3
M	Highlands	8100 S. University	060080002F01	Trailer	Vacant land at edge of residential area	56.15	9.12	2.59	0
N	Englewood	3600 S. Elati	062080824F05	Municipal building	Light commercial near major shopping center	60.00	13.43	6.23	e
O	Montbello	4845 Oakland	062080817F05	School	Offices and small warehouses (suburban commercial)	41.05	0.0	3.60	e

[a] 16.00 or 25.00. [b] 65.13 or 56.09. [c] 9.97 or 13.51. [d] Permanent site with no 1981 data. [e] Temporary site with no 1981 data.

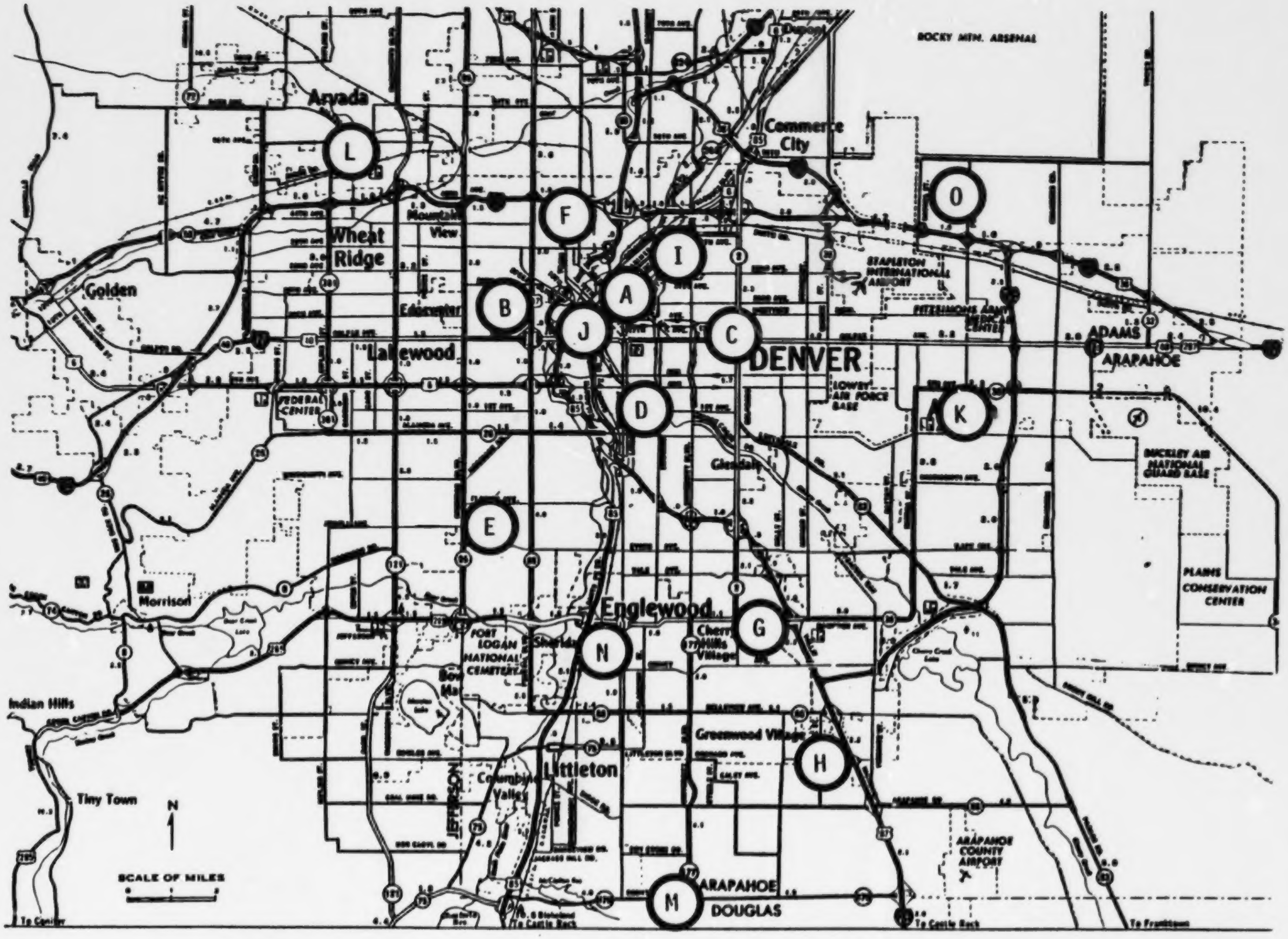

ROCKY MTN. ARSENAL
Arvada
L
Commerce City
O
F
Wheat Ridge
Mountain View
I
Golden
B
A
STAPLETON INTERNATIONAL AIRPORT
Edgewater
J
C
FITZSIMONS ARMY MEDICAL CENTER
ADAMS
ARAPAHOE
Lakewood
DENVER
LOWRY AIR FORCE BASE
FEDERAL CENTER
D
K
Glendale
BUCKLEY AIR NATIONAL GUARD BASE
E
Morrison
PLAINS CONSERVATION CENTER
Englewood
G
FORT LOGAN NATIONAL CEMETERY
Sheridan
N
Cherry Hills Village
Indian Hills
Greenwood Village
H
Littleton
Columbine Valley
JEFFERSON
Tiny Town
N
ARAPAHOE COUNTY AIRPORT
SCALE OF MILES
M
ARAPAHOE
DOUGLAS
To Conifer
To Castle Rock
To Franktown

Figure 3-3. Locations of fixed-site monitors.

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The quantities RDEN and TDEN relate to the average residential and traffic densities of the census tract containing each monitor and are explained in Section 5.1. The land use designation pertains to the neighborhood in the immediate vicinity of each monitor. Appendix G contains more detailed descriptions of the area surrounding each site. Site selection, data acquisition, and quality assurance activities are described in Reference 3.

3.9 REFERENCES

1. Ott, Wayne. Exposure Estimates Based on Computer Generated Activity Patterns. Paper No. 81-57.6. Presented at the 74th Annual Meeting of the Air Pollution Control Association. Philadelphia. June 21-26, 1981.

2. Johnson, Ted, and Roy Paul. The NAAQS Model (NEM) Applied to Carbon Monoxide. PEDCo Environmental, Inc., 505 South Duke Street, Durham, North Carolina 27701. September 1983.

3. The Denver Carbon Monoxide Study: Fixed Station Siting, Data Acquisition, and Quality Assurance. Air Pollution Control Division, Department of Health, State of Colorado. September 1983.

SECTION 4

DATA COLLECTION AND PROCESSING

This section describes the various procedures followed in administering the CMIQ, the study questionnaire, and the field version of the screening questionnaire; in assigning subjects to sampling periods; in collecting and processing PEM, activity diary, and breath sample data; and in maintaining and calibrating the PEM's. A more detailed description of PEM maintenance and calibration is contained in a separate document.[1]

4.1 ADMINISTRATION OF FIELD VERSION OF SCREENING QUESTIONNAIRE

4.1.1 Donnelley Listings with No Previous Telephone Contact

RTI provided PEDCo with the addresses of 242 Donnelley listings that had not been screened because RTI was unable to make telephone contact. A representative of CMR visited each of these addresses and attempted to administer a field version of the screening questionnaire. Appendix H contains the instructions followed in conducting this survey and in completing the control cards and work sheets used for documentation and record keeping.

4.1.2 Missed Housing Units

RTI provided PEDCo with the addresses of 150 Donnelley listings selected according to the sampling protocol described in Section 2.2. Each of these addresses served as a start point of a search for HU's missing from the Donnelley list. Nearby HU's were surveyed according to the count and list procedure outlined in Table 4-1 until another Donnelley listing was identified. An attempt was made to administer the field screening questionnaire to each of the non-Donnelley households identified during the survey. Appendix H contains the instructions followed in carrying out the survey and in completing the associated control cards and work sheets.

TABLE 4-1. COUNT AND LIST PROCEDURE FOR SURVEY OF MISSING HOUSING UNITS

1. Go to initial housing unit (i.e., the address at top of worksheet). Do 2 if initial housing unit is one of two or more units with same address (e.g., apartment complex); otherwise do 3.
2. Visit "higher" units at same address. If units are numbered, visit in ascending order. If units are not numbered, visit each floor in clockwise order and move up to next floor when you reach the staircase or elevator you came up on. When "highest" unit has been visited, do 3.
3. Moving in a clockwise direction, visit each housing unit in the block. Do 2 whenever two or more housing units are associated with the same address. When you reach northeast corner of block, do 4.
4. Refer to segment map. Find number of block just completed. Locate block with next higher number. If no block has a higher number, locate block with lowest number in segment. Go to address at northeast corner of indicated block. Do 3.
5. Stop when a housing unit on the Donnelley list for the segment has been visited or when all housing units in the segment have been visited.

4.2 ASSIGNMENT OF SUBJECTS TO SAMPLING PERIODS

RTI provided four lists of potential subjects to PEDCo: a primary sample containing 595 eligible individuals; two supplementary samples, each containing 54 eligible individuals; and a third supplementary sample containing 297 eligible individuals. The names in each group were listed in random order. CMR called the persons in the primary sample in the order listed, administered the CMIQ (Section 4.3), and offered each person the first unfilled slot in the study. If he or she refused, the next unfilled slot was offered and so on until the respondent agreed to a slot or indicated a strong reluctance to be part of the study. This process was repeated with each of the supplementary samples and with the 139 names provided from the field screening activities (see Figure 2-1). The results of all telephone calls, including scheduled appointment times and reasons for refusal, were recorded on a special control card (see Appendix I).

RTI used a different strategy for the Washington study.[2] Potential subjects were offered three slots with predetermined dates. If they refused, they were not included in the study. Use of such a procedure in Denver would have resulted in an unacceptably high refusal rate.

4.3 ADMINISTRATION OF CMIQ

Appendix B contains the CMIQ. An attempt was made to administer this questionnaire to each person selected to be in the study. In some cases, an immediate refusal to proceed after question A.5 prevented completion of the CMIQ. In other cases, the respondent answered all questions on the CMIQ, but did not accept any of the dates offered for participation in the study. Consequently, CMIQ's were completed by all persons who actually participated in the study and a few additional persons who did not participate.

4.4 ACTIVITIES INVOLVING INTERVIEWERS

CMR employed 13 part-time interviewers during the course of this study. The interviewers delivered PEM's, activity diaries, and study questionnaires to the subjects according to their scheduled appointments. Each subject was asked to participate in the study for two consecutive 24-hour sampling periods. Because different PEM's and activity diaries were used for the two sampling periods, an interviewer visited each subject on three consecutive days. In most cases, the first PEM and activity diary were delivered between 7 p.m. and 9 p.m. on day A and picked up 24 hours later on day B. During pickup, problems encountered during the first sampling period were addressed and a second PEM and a second activity diary were delivered. These were picked up 24 hours later on day C. Breath samples were taken during pickups on days B and C. A study questionnaire was delivered on day A and picked up on day C. Table 4-2 presents a schedule for these and associated activities. Table 4-3 presents instructions for administering the breath sample. Appendix I contains the control cards used to schedule and document interview activities.

For the interviewer's convenience, all study materials (control cards, activity diaries, study questionnaire, breath bags and clamps, consent form, incentive, and receipt) were placed into an 8.5 by 14 inch manila envelope to which an identification label was attached. Each label contained spaces for PID number, beginning and ending dates, PEM numbers, and a check list for enclosed materials (Figure 4-1).

TABLE 4-2. PROCEDURE FOLLOWED BY INTERVIEWERS DURING PEM PHASE OF STUDY

1. Interviewer receives respondent's PID, address, phone number, and appointment time from CMR.

DAY A 2. Interviewer attempts to verify appointment and respondent's address before leaving home. If respondent cancels appointment, interviewer should call CMR for instructions. Otherwise, interviewer should report to CMR prior to scheduled appointment. If verification was not made from interviewer's home, it should be attempted from CMR. If verification attempts fail, the appointment is still kept.

3. Interviewer obtains control cards, PEM, activity diary, consent form, and study questionnaire from field laboratory. Interviewer checks that PID and monitor numbers have been entered on all applicable documents.

4. Interviewer goes to respondent's home at scheduled time.

5. Interviewer explains study and has respondent complete consent form.

6. Interviewer gives PEM, activity diary, and study questionnaire to respondent and explains their use.

7. Interviewer makes first entry in activity diary as example (write "interview" under Activity). Respondent makes second entry.

8. Interviewer makes appointment for return visit in 24 hours.

DAY B 9. Interviewer obtains breath bag, second PEM, and second activity diary from field lab prior to appointment. Interviewer checks that PID and monitor numbers have been entered on all applicable documents.

10. Interviewer goes to respondent's home at appointed time.

11. Interviewer makes initial entry in second activity diary (write "interview" under Activity).

12. Interviewer receives first PEM and makes final entry in first activity diary (write "final entry" under Activity).

13. Interviewer takes breath sample and ambient CO measurement (see Table 4-3). Interviewer records "ambient CO start" and "ambient CO stop" times on page of first activity diary marked "final entry."

14. Interviewer scan-edits first activity diary.

(continued)

TABLE 4-2 (continued)

15. Interviewer enters appropriate data on control card.

16. Interviewer makes appointment for return visit in 24 hours.

17. Respondent makes next entry in second activity diary.

18. Interviewer returns consent form, first PEM, first activity diary, and first breath sample to field lab.

DAY C 19. Interviewer returns to field lab prior to final appointment to pick up second breath bag.

20. Interviewer goes to respondent's home at scheduled time.

21. Interviewer receives second PEM and makes final entry in second activity diary (write "final entry" under Activity).

22. Interviewer takes breath sample and ambient CO measurement (see protocol). Interviewer records "ambient CO start" and "ambient CO stop" times on page of second activity diary marked "final entry."

23. Interviewer scan-edits second activity diary.

24. Interviewer scan-edits study questionnaire and completes last page.

25. Interviewer enters appropriate data on control card.

26. Interviewer pays respondent. Both sign receipt. Interviewer keeps receipt.

27. Interviewer returns receipt, study questionnaire, control cards, second PEM, second activity diary, and second breath sample to field lab.

TABLE 4-3. PROTOCOL FOR COLLECTION OF BREATH SAMPLE

1. After making final activity diary entry, interviewer says: "Now I would like to measure the carbon monoxide in your breath. This is a simple procedure, takes less than 5 minutes, and only requires that you hold your breath for a few seconds and then blow it into this bag."

2. After obtaining subject's consent, interviewer explains the following procedure:

   a. Squeeze all the air out of the bag and inlet tube.

   b. Take a few normal, relaxed breaths.

   c. Exhale completely.

   d. Take a deep breath and hold it for 20 seconds (check with second hand).

   e. Blow some of the air from your lungs. Breathe out until your chest feels relaxed and collapsed. It is important that the sample consist of the air from the alveolar area of the lungs. The best sample is the one where you are really straining to force your air into the bag.

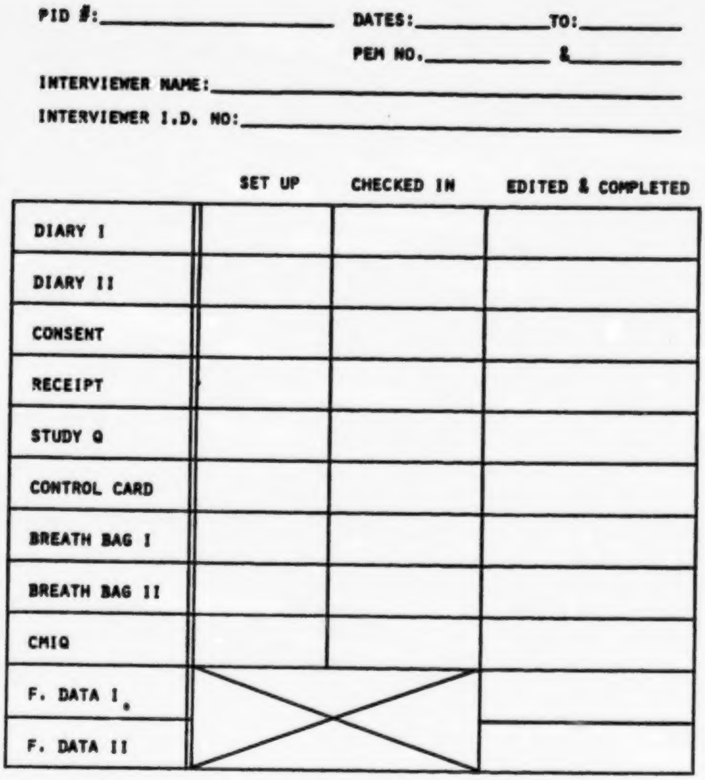
   f. Blow your remaining breath into the bag, making certain not to inhale any more air before or during this part of the process. If you should happen to inhale wait two minutes and start the procedure over.

   g. Seal the sample bag carefully being sure none of the air escapes. Use the stopper that is provided to place in the inlet tube.

   h. For an accurate analysis the bag should be filled to capacity. It should become a firm pillow. If the volume of collected breath is insufficient (the bag is still soft), fold the inlet tube and hold tightly to seal the bag, wait two minutes, and repeat the process. Breathe out more air than before so that the bag is completely filled.

3. While the subject is performing the above procedures, interviewer pushes activity button on PEM, records time, waits 60 seconds, pushes activity button again, and records time. The two time readings should be recorded at the bottom of the last completed page of the activity diary. Label the first reading "ambient CO start" and the second reading "ambient CO stop."

4. The interviewer returns the sample bag to the lab unopened.



PID #:____________________ DATES:__________TO:________
PEM NO.__________ &________
INTERVIEWER NAME:____
INTERVIEWER I.D. NO:______________________________________

	SET UP	CHECKED IN	EDITED & COMPLETED
DIARY I			
DIARY II			
CONSENT			
RECEIPT			
STUDY Q			
CONTROL CARD			
BREATH BAG I			
BREATH BAG II			
CMIQ			
F. DATA I	☒	☒	
F. DATA II	☒	☒	

Figure 4-1. Label for study materials envelope.

4.5 QUALITY ASSURANCE AND ROUTINE MAINTENANCE OF PEM'S

Quality assurance activities associated with the PEM's included daily zero-span checks, frequent multipoint calibrations, special studies evaluating precision, and two independent audits. In addition, each PEM required routine maintenance and repair. The results of these activities are summarized in Section 6.3.

4.5.1 Daily Zero-Span Checks

Table 4-4 presents an abbreviated description of the calibration/programming procedure performed daily on each outgoing PEM. After calibration and programming were completed, PEM's were delivered to the subjects according to the procedure described in Table 4-2. A post zero-span check was performed on each PEM when it was returned to the laboratory. The post zero-span check is identical to the initial zero-span check except that no adjustments are made. A sample zero-span sheet is presented in Figure 4-2. Table 4-5 lists the steps followed in programming each PEM.

Occasionally PEM's were returned that malfunctioned during the sampling period. When this occurred, an attempt was made to repair the PEM so that the post zero-span check could be performed. PEM's returned with low flows were checked under those conditions. Data obtained from PEM's exhibiting a span shift of more than ±10 percent were flagged and omitted from certain statistical analyses.

4.5.2 Multipoint Calibrations

Multipoint calibrations were performed on each PEM prior to its first use in the field and at the completion of the field sampling in March 1983. A PEM was also recalibrated following any change to the MAGUS data system. In addition, a PEM was recalibrated whenever it exhibited a span shift greater than ±10 percent based on daily zero-span checks. Reference gases for calibrations were verified by EPA and traceable to the National Bureau of Standards.

4.5.3 Precision Checks

PEM precision during normal use was evaluated by having a subject or technician carry two monitors through a 24-hour sampling period and recording the measurements taken by each PEM on a field data sheet. Approximately 200

TABLE 4-4. PROCEDURE FOR DAILY PEM CALIBRATION AND PROGRAMMING

1. Turn on zero air system.
2. Line up PEM's in rows of three or four such that each may be reached by a line from the calibration manifold. Attach sample lines to each PEM.
3. Record information on calibration sheet--pre or post zero-span, date, time, analyst, calibration standard, calibration ID, barometric pressure, temperature, and PEM ID's (see Figure 4-2, Daily Zero-Span Sheet).
4. Measure dilution air from zero air system and calculate the required pollutant flow for a span concentration of 40 ppm CO (± 5%). Set pollutant to desired level, measure, and record value in field log.
5. Program PEM's while on charge. Turn on pumps in the "log" mode (see Table 4-5, Programming Procedure).
6. Compare the response of each PEM with the Bendix recorder response. Once the Bendix has lined out and a baseline has been established, assume each PEM should also read zero.
7. Record all PEM zero readings on calibration sheet in spaces under "Unadjusted LCD Zero."
8. Inject span gas.
9. Compare each PEM response with the Bendix recorder response as in Step 6.
10. Record all PEM span readings on calibration sheet in spaces under "Unadjusted LCD Span."
11. Adjust PEM span output if difference exceeds ± 5 percent.
12. Inject zero gas.
13. Repeat Step 6.
14. Adjust PEM zero output if zero reading exceeds ± 1 ppm CO.
15. Inject span gas and check for reproducibility with adjusted value in Step 11.

(continued)

TABLE 4-4 (continued)

16. Inject zero gas and check for reproducibility with adjusted value in Step 14.

17. Repeat Steps 15 and 16 and 11 to 14 as necessary until acceptable reproducibility is achieved.

18. Record PEM zero readings on calibration sheet in spaces under "Adjusted LCD Zero."

19. Change the mode of the first PEM in the calibration lineup from the "log" mode to the "clock" mode.

20. Push the activity button of each PEM in the order in which they are lined up. Record the time from first PEM as the "start" time for zero gas calibration on the calibration sheet.

21. Wait 5 minutes.

22. Repeat Step 20, but record time as the "stop" time for zero gas on calibration sheet.

23. Change the mode of the first PEM back into "log" mode.

24. Record all PEM zero readings on calibration sheet in spaces under "Adjusted LCD Zero."

25. Inject span gas.

26. Repeat Steps 18 to 24 with span gas. Record span values on calibration sheet in spaces under "Adjusted LCD Span."

27. Inject zero gas.

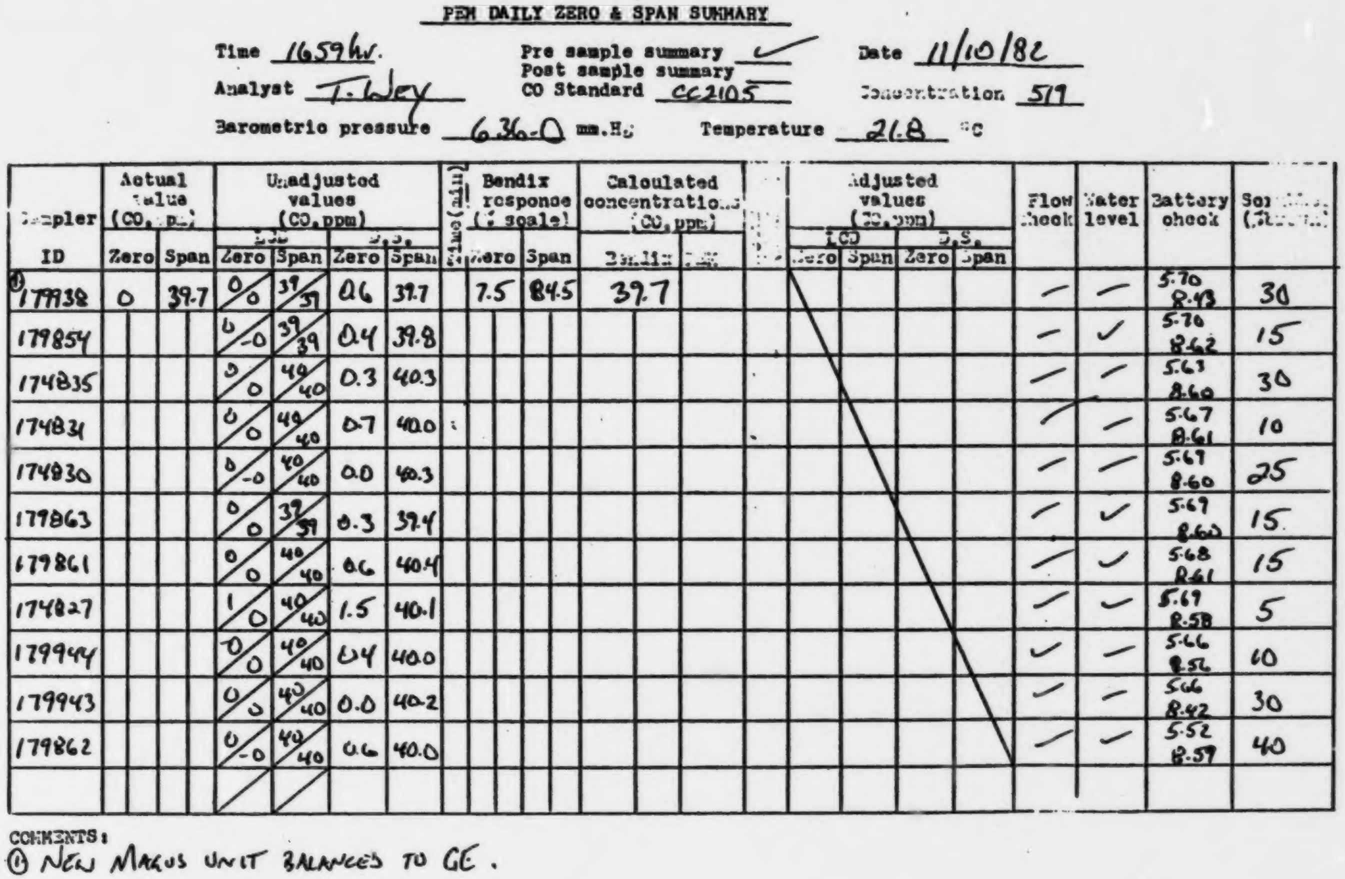
28. Turn off all PEM sample pumps once zero output is noted.

29. Turn off zero air system and pollutant cylinder.

30. Remove one PEM at a time from its charger and dump the data stored in the data subsystem via the "display" mode. Record the values on the calibration sheet in the spaces under "Adjusted D.S. Zero" and "Adjusted D.S. Span."

31. Check cell water level, pump flow, and battery voltages of each PEM. Record these conditions on the calibration sheet.

32. Reprogram each PEM and leave in the "clock" mode on charge.



PEM DAILY ZERO & SPAN SUMMARY

Time 1659hr.
Pre sample summary ✓
Date 11/10/82
Post sample summary
Analyst T. Wey
CO Standard CC2105
Concentration 519
Barometric pressure 636.0 mm.Hg
Temperature 21.8 °C

Sampler ID	Actual value (CO, ppm) Zero	Actual value (CO, ppm) Span	Unadjusted values (CO, ppm) LCD Zero	Unadjusted values (CO, ppm) LCD Span	Unadjusted values (CO, ppm) D.S. Zero	Unadjusted values (CO, ppm) D.S. Span	Time (min)	Bendix response (% scale) Zero	Bendix response (% scale) Span	Calculated concentration (CO, ppm) Bendix	Calculated concentration (CO, ppm) [illegible]	[illegible]	Adjusted values (CO, ppm) LCD Zero	Adjusted values (CO, ppm) LCD Span	Adjusted values (CO, ppm) D.S. Zero	Adjusted values (CO, ppm) D.S. Span	Flow check	Water level	Battery check	So[illegible] ([illegible])
①179938	0	39.7	0/0	39/39	0.6	39.7		7.5	84.5	39.7							✓	✓	5.70 8.43	30
179854			0/-0	39/39	0.4	39.8											✓	✓	5.70 8.62	15
174835			0/0	40/40	0.3	40.3											✓	✓	5.63 8.60	30
174831			0/0	40/40	0.7	40.0											✓	✓	5.67 8.61	10
174830			0/-0	40/40	0.0	40.3											✓	✓	5.67 8.60	25
179863			0/0	39/39	0.3	39.4											✓	✓	5.69 8.60	15
179861			0/0	40/40	0.6	40.4											✓	✓	5.68 8.61	15
174827			1/0	40/40	1.5	40.1											✓	✓	5.69 8.58	5
179944			0/0	40/40	0.4	40.0											✓	✓	5.66 8.56	10
179943			0/0	40/40	0.0	40.2											✓	✓	5.66 8.42	30
179862			0/-0	40/40	0.6	40.0											✓	✓	5.52 8.59	40

COMMENTS:
① NEW MAGUS UNIT BALANCES TO GE.

Figure 4-2. Sample completed zero-span sheet.

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TABLE 4-5. PEM PROGRAMMING PROCEDURE

1. Set "Alog" to "yes."
2. Set "clr" to "sclr" then "clrd."
3. Set "day" to desired day, usually 1.
4. Set "hour" to actual clock hour, military time.
5. Set "min" to actual clock minute, military time.
6. Set "Alog" back to "yes."
7. Switch "clr" to "sclr" and hold momentarily.
8. Activate "log" and hold momentarily.
9. Switch "clock" on and leave in this mode for sampling period.

Note: Mode switch in RIGHT position will enable mode change when activity switch is pressed. Mode switch in LEFT position will set function when activity switch is pressed.

- "clr" mode clears logger.
- "sclr" mode initiates the clock and resets the display mode.
- "clrd" mode hardclears (resets all logged data in the data subsystem to zero).

paired values of 60 minutes or less were obtained through the use of 10 pairs of PEM's.

Intermethod precision was evaluated by comparing PEM measurements with measurements taken simultaneously by the reference nondispersive infrared method used by the State and local agencies for compliance monitoring. These comparisons, which were performed by the Air Pollution Control Division of the Colorado Department of Health, were made by attaching the inlet sample line of the PEM to the manifold supplying sample ambient air to one of the 15 fixed-site monitors operating in the Denver area during the study. Eighty-five pairs of hourly average CO values were collected.

4.5.4 Independent Audits

The Quality Assurance Division, Environmental Monitoring Systems Laboratory, EPA, performed two systems and performance audits of the monitoring program. The first audit was conducted at the start of the project, November 15-21, 1982. The second audit was conducted February 21-25, 1983, near the end of the study. Audits included accuracy evaluations of fixed-site monitors, PEM's, and breath bags. Audit procedures and results are described in detail in two reports prepared by Bernard and Bowen.[3,4] A summary of the audit results is provided in Section 6.3.

4.5.5 Routine Maintenance

The water level in each sensor cell was checked on a regular basis, and water was added as needed. Flow rates were also routinely checked and adjusted. When acceptable flow rates were not achieved, the PEM pump was disassembled and cleaned. Battery packs were discharged on a weekly basis and fully charged daily before delivery to subjects. Additional details on PEM calibration, programming, and maintenance are provided in reports prepared by PEDCo[1] and Rockwell International.[5] Problems encountered during the study are discussed in Section 6.3.

4.6 BREATH SAMPLE ANALYSIS

Breath samples were analyzed with a General Electric CO-3 dosimeter. The CO-3 was calibrated along with the PEM's during the daily pre and post zero-span checks. It was also subjected to a full five multipoint calibration on a routine basis. Each breath sample was analyzed on the evening it was checked in. The sample was drawn through a special filter (Figure 3-2), which contained an activated charcoal medium and potassium permangenate scrubber for removal of alcohol interferences associated with the CO-3. The CO-3 was allowed to sample the entire breath bag or enough sample to produce a stable reading on the CO-3 liquid crystal display (LCD). The LCD reading was then corrected to the actual CO concentration according to that day's pre and post zero-span calibration.

4.7 CODING OF PEM AND ACTIVITY DIARY DATA

Data stored in each PEM were transferred from the PEM data subsystem to a field data sheet the night the PEM was checked in. The data were stored in a set of sequential registers (113 maximum). To transfer these data, the PEM was switched to "display" mode. Then by pushing the activity button repeatedly, each register's contents were displayed in sequence from the earliest entry to the most recent entry. After data transfer was completed, all data were displayed again to permit a final check of the data sheet entries.

Data from each activity diary were converted into alphanumeric codes (Section 3.6), which were recorded on the appropriate field data sheet next to the corresponding time and CO concentration. A Denver census tract street directory,[6] a cross reference directory,[7] road maps, and telephone directories were used to convert street addresses to census tract numbers. In approximately 20 percent of the cases, the participant was contacted to clarify information being coded onto a field data sheet.

4.8 COMPLETION OF SUMMARY SHEET

CMR attempted to schedule 10 or more subjects for each day of the study. The names and PID numbers of the scheduled subjects for each day were entered on a separate Summary Sheet (Figure 4-3). At the end of each sampling period, codes describing the status of subject, PEM, activity diary, and breath sample were entered in the spaces next to each PID number. These codes are explained at the bottom of the Summary Sheet. Data from the summary sheets were regularly tabulated, and the results were transmitted to the project manager for evaluation. Appendix J presents a tabulation of the summary sheet data for the entire study period.

SUMMARY SHEET

Day ______ Date ____________ Number complete ______

	Name	PID	Subject	PEM	Diary	Breath
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
11.						
12.						
13.						
14.						
15.						
		Total okay				

Codes

Subject

11: okay
12: refusal
13: rescheduled
14: not eligible
15: other

PEM

21: okay
22: malfunction
23: failed zero-span
24: damaged
25: other

Diary

31: okay
32: incomplete
33: incorrect
34: lost
35: other

Breath

41: okay
42: refusal
43: leak
44: illness
45: other

Figure 4-3. Summary sheet.

It should be noted that the assignment of Codes 22-25 and 32-35 did not invalidate the PEM and activity diary data but rather served to call attention to possible data problems. The ultimate validity of each data set was indicated by a three-digit data quality code (Section 4.11) assigned after completion of various data validation procedures.

4.9 DATA VALIDATION

PEDCo and CMR jointly edited all data forms completed by each subject (CMIQ, study questionnaire, and activity diaries). PEDCo also edited all field data sheets before they were keypunched. Editing consisted of visual checks for completeness, accuracy, and logical consistency of all data entries. The following sections describe additional validation techniques applied to data from the field data sheets, study questionnaires, and fixed monitoring sites.

4.9.1 Field Data Sheets

The Denver CO Study produced approximately 900 field data sheets, each consisting of from two to six pages, depending on the number of diary entries. When properly keypunched, each field data sheet yielded a data set containing between 24 and 96 lines of data. Table 4-6 presents the format used for keypunching data items from the field data sheet. If an item was blank on the field data sheet, the corresponding spaces in the computer file were left blank (except in the case of concentration, where the code 9999 was entered).

PEDCo developed a computer program to verify each individual data set. Table 4-7 lists the anomalies detected by the verification program and the three-digit codes used to identify these anomalies. Three types of anomalies are listed (X, Y, and Z). Type X anomalies (codes 111-132) include missing or incorrect entries in columns 1-19. Because the entries in these columns should be identical for all lines, only the first line of each data set was checked for Type X anomalies. Supplementary files containing valid monitor ID's, PID's, and sampling dates were used to detect anomalies with Codes 112, 122, and 132. Type Y anomalies (Codes 202-221) are defined as the nonoccurrence of a particular value throughout an entire data set. Type Z anomalies (Codes 300-920) include missing or incorrect entries in columns 22-56. Every line in each data set was individually checked for Type Z anomalies.

TABLE 4-6. FORMAT FOR KEYPUNCHING FIELD DATA SHEETS

Item	Columns	Blanks permitted?
Monitor ID	1-6	No
PID	7-13	No
Date Sampled	14-19	No
Sequence No.	20-21	No
Time	22-25	No
CO conc., ppm	26-29	No
A (activity code)	30-31	No
B (location code)	32-33	Yes
C (census tract)	34-38	Yes
D1 (census tract)	39-43	Yes
D2 (census tract)	44-48	Yes
D3 (travel mode code)	49-50	Yes
E1 (garage code)	51-52	Yes
E2 (gas stove code)	53-54	Yes
F (smoking code)	55-56	Yes
Calibration class code[a]	57-59	No
Data quality code[a]	60-62	No
Duration (minutes)[a]	63-64	No

[a] Added during creation of SAMPLE-DATA file (Section 4.10).

TABLE 4-7. CODES FOR FLAGGING ANOMALIES

Code	Anomaly
111	Monitor ID missing
112	Monitor ID not in supplementary file
121	PID missing
122	PID not in supplementary file
131	Date missing
132	Date not in supplementary file
202	No occurrence of B = 02
208	No occurrence of A = 08
209	No occurrence of A = 09
217	No occurrence of A = 17
218	No occurrence of A = 18
219	No occurrence of A = 19
220	No occurrence of A = 20
221	No occurrence of A = 21
300	Time blank
301	Time > 2359
302	Time (seq = x) > time (seq = x - 1) + 100
400	CO conc. blank
401	40.0 ≤ CO conc. < 100.0
402	100.0 ≤ CO conc. < 999.9
499	CO conc. = 999.9
500	A blank
501	A = 01 and B ≠ 01, 07, 09, 52, or 72
503	A = 03 and B ≠ 02
504	A = 04 and B ≠ 02
505	A = 05 and B ≠ 02
506	A = 06 and B ≠ 07, 71, or 76
512	A = 12 and B ≠ 05, 62, or 80
513	A = 13 and B ≠ 02, 07, 56, 62, 73, 76, 77, 79, or 80
515	A = 15
516	A = 16
519	A = 19 and any entry in B, C, D1, D2, D3, E1, E2, or F
521	A > 21
600	B ≠ 01-05, 07, 09, 50-62, or 70-80
601	B = 01 and A ≠ 01, 15, or 19
602	B = 02 and A = 01, 07, 12, or 13
603	B = 03 and A ≠ 02, 03, 08, 10, 11, 14, or 15-21
604	B = 04 and A ≠ 02, 07, or 15-21
605	B = 05 and A ≠ 08, 11, 12, or 14-21

(continued)

TABLE 4-7 (continued)

Code	Anomaly
609	B = 09
650	B = 50
651	B = 51 and A = 03, 07, or 08-12
652	B = 52 and A = 03-06, or 08-10
653	B = 53 and A ≠ 02, 07, or 14-21
654	B = 54 and A ≠ 02, 07, 14, or 15-21
655	B = 55 and A ≠ 02, 07, 14, or 15-21
656	B = 56 and A ≠ 02, 11, 13, or 14-21
657	B = 57 and A ≠ 02, 11, or 15-21
658	B = 58 and A ≠ 02, 07, or 15-21
659	B = 59 and A ≠ 02, 10, 11, or 14-21
660	B = 60 and A ≠ 02, 08, 11, or 14-21
661	B = 61 and A ≠ 02, 11, or 14-21
670	B = 70
671	B = 71 and A = 03, 07, or 08-12
672	B = 72 and A = 03-06, or 08-10
673	B = 73 and A = 03-06, or 08-10
674	B = 74 and A ≠ 02, 07, or 15-21
675	B = 75 and A ≠ 02, 13, or 15-21
676	B = 76 and A = 01, 03, 05, 07, or 12
677	B = 77 and A ≠ 02, 11, or 13-21
678	B = 78 and A ≠ 02, 11, or 13-21
679	B = 79 and A ≠ 02, 11, or 13-21
699	B blank and A ≠ 16 or 19
700	C, D1, and D2 blank when A ≠ 16 or 19
701	C < 101 or C > 14100
702	C entry and B = 01
703	C entry and D1 entry
704	C entry and D2 entry
801	D1 entry and D2 blank
802	D2 entry and D1 blank
803	D1 < 101 or D1 > 14100
804	D2 < 101 or D2 > 14100
811	B = 01 and D1 blank
812	B = 01 and D2 blank
813	B = 01 and D3 blank
821	D1 entry and B ≠ 01
822	D2 entry and B ≠ 01
823	D3 entry and B ≠ 01, 51, 52, 71, 72, or 73
830	D3 ≠ 01-05 or 90-97
890	D3 = 90
911	E1 blank and B = 02, 03, 04, 05, or 50-62
912	E2 blank and B = 02, 03, 04, 05, or 50-62
920	F blank and any B entry

Figure 4-4 presents an example of the program output. DATE, PID, and MONITOR are taken from columns 14-19, 7-13, and 1-6, respectively, of line 1 of the data set. Codes for all detected Type X anomalies are listed after TYPE X CODES. Codes for all detected Type Y anomalies are listed after TYPE Y CODES. Anomaly Code 218 indicates that activity Code 18 (final entry) does not appear anywhere in the data set. The data set, omitting columns 1-19, is printed out below the line reading DATA SET AND TYPE Z CODES. Type Z anomalies are indicated by listing the corresponding code(s) in columns 60-80 of the appropriate line. Anomaly Code 302 indicates that more than 60 minutes have elapsed between successive time entries. ANOMALIES DETECTED is the total number of anomalies detected in the data set.

All data from the field data sheets were checked by using this program and two supplementary validation programs. All anomalies identified by these programs were evaluated and revised or removed as appropriate.

4.9.2 Study Questionnaires

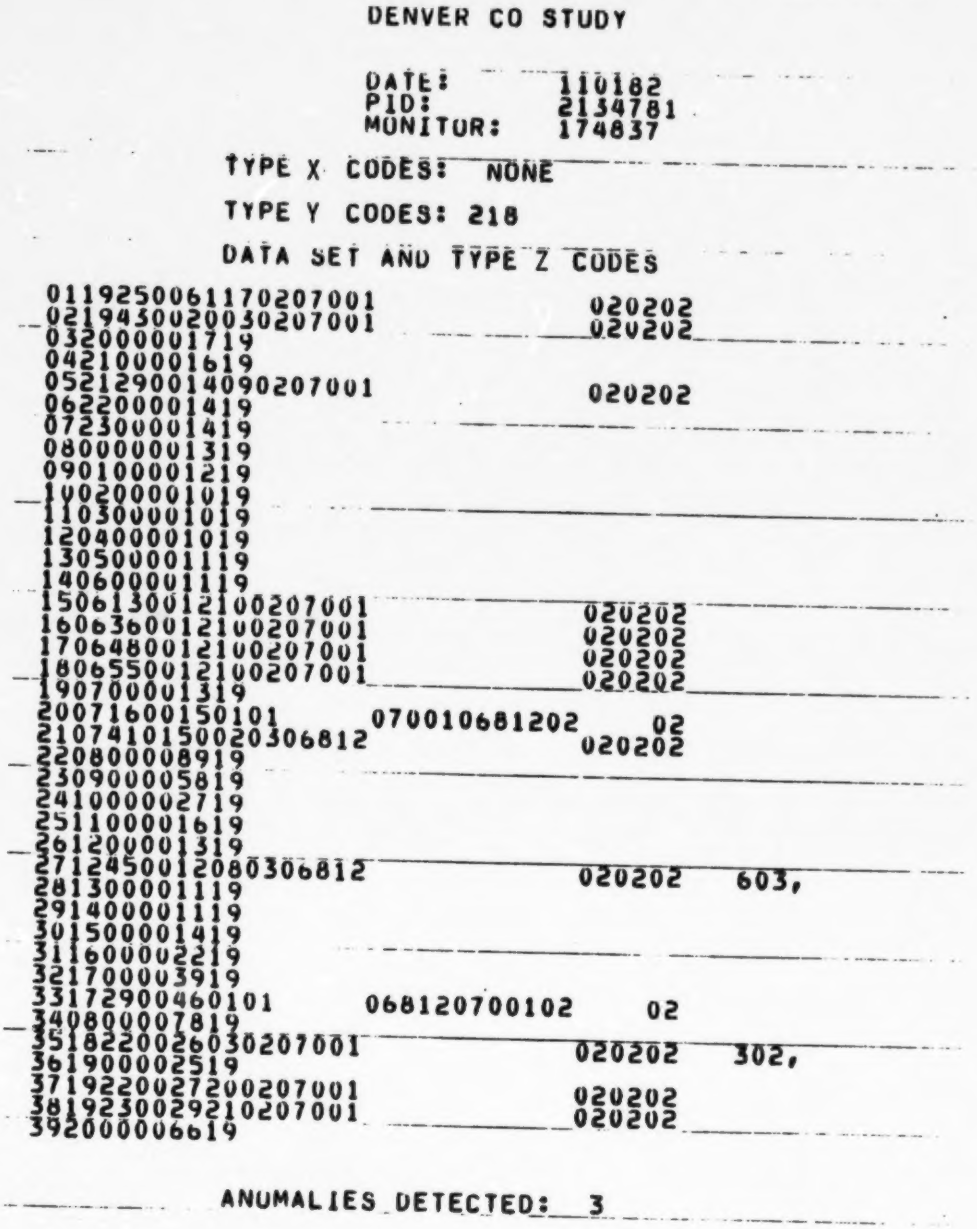
Appendix C contains a copy of the study questionnaire completed by each study participant. Table 4-8 lists data items from the questionnaire that PEDCo entered into a computer file for use in statistical analyses of potential exposure factors. The items selected were those judged likely to affect exposure that did not duplicate data contained on the field data sheets.

Table 4-8 also includes instructions for keypunching the data. In cases when the participant was requested to fill in a blank (e.g., occupation), a separate code was created for each response.

The completed file was validated by checking for illegal or missing response codes and by checking the frequencies of responses to related data items for logical inconsistencies.[8] All anomalies identified through these procedures were investigated, and data found to be in error were revised or removed as appropriate.

4.9.3 Fixed-Site Data

Fixed-site data were reviewed and validated by the Air Pollution Control Division (APCD) of the Colorado Department of Health. Validation procedures employed by APCD included checks of instrument calibration and data transmission, comparison of data printouts with strip charts, and evaluation of



```
                   DENVER CO STUDY

                   DATE:          110182
                   PID:           2134781
                   MONITOR:       174837

          TYPE X  CODES:  NONE

          TYPE Y  CODES: 218

          DATA SET AND TYPE Z CODES

011925006117020700l                        020202
02194300200302070001                       020202
032000001719
042100001619
0521290014090207001                        020202
062200001419
072300001419
080000001319
090100001219
100200001019
110300001019
120400001019
130500001119
140600001119
1506130012100207001                        020202
1606360012100207001                        020202
1706480012100207001                        020202
1806550012100207001                        020202
190700001319
20071600150101       070010681202            02
2107410150020306812                        020202
220800008919
230900005819
241000002719
251100001619
261200001319
2712450012080306812                        020202    603,
281300001119
291400001119
301500001419
311600002219
321700003919
33172900460101       068120700102            02
340800007819
3518220026030207001                        020202    302,
361900002519
3719220027200207001                        020202
3819230029210207001                        020202
392000006619

          ANOMALIES DETECTED:   3
```

Figure 4-4. Sample output of validation program.

TABLE 4-8. DATA ITEMS FROM STUDY QUESTIONNAIRE PROPOSED FOR EXPOSURE FACTOR ANALYSIS

Data item	Question	Column(s)	Permitted entries
PID	PID no.	1-7	7-digit number
Housing type	1	8-9	01-07
Living area (sq ft)	2	10-14	5-digit number equal to area in square feet
Packs smoked per week	3d	15,16	01-04
CO sources in residence	4a	17	1-3
	4b	18	1-3
	4c	19	1-3
	4d	20	1-3
	4e	21	1-3
	4f	22	1-3
	4g	23	1-3
	4h	24	1-3
	4h-spec	25	Assign 1-digit number
Energy-saving devices in residence	5a	26	1-3
	5b	27	1-3
	5c	28	1-3
	5d	29	1-3
	5e	30	1-3
	5e-spec	31	Assign 1-digit number
Fans in residence	6a	32	1,2
	6b	33	1,2
	6c	34	1,2
	6c-spec	35	Assign 1-digit number
Heating system in residence	7	36,37	01-08, 10, 94, assign 2-digit number in place of 09
Air-conditioning in residence	8	38,39	01-03
Pollution sources near residence	10a	40	1,2
	10b	41	1,2
	10c	42	1,2
	10d	43	1,2
	10e	44	1,2
Year of automobile	18	45,46	Last 2-digits of year, leave blank if automobile not used
Type of enclosed work area (EWA)	22	47,48	01-05, assign 2-digit number in place of 06

(continued)

TABLE 4-8 (continued)

Data item	Question	Column(s)	Permitted entries
Square feet in EWA	23	49-54	6-digit number equal to area in square feet
Air-conditioning in EWA	24	55,56	01-03
Fan in EWA	25	57,58	01-04
Work place heating system	27	59,60	01-08, 10, 94, assign 2-digit number in place of 09
Pollution sources near work	28a	61	1,2
	28b	62	1,2
	28c	63	1,2
	28d	64	1,2
	28e	65	1,2
Occupation type	29	66-68	Assign 3-digit Bureau of Census code
Sex	35	69,70	01,02
Age	36	71,72	2-digit number
Construction of residence	B, p. 12	73,74	01-05, assign 2-digit number in place of 06

extreme values and unusual pollutant patterns.[9] As an additional check on the data, PEDCo analyzed the hourly average values reported by each fixed site using a statistical validation procedure referred to as the Jump Test.[10] The differences between successive hourly average values were calculated and grouped by time of day. Differences exceeding a group-specific critical value were identified, and the corresponding hourly average values were flagged. The flagged hourly average values were then checked against adjacent values at the same site to see if they fit the general pattern for the day (sequential consistency check) and against simultaneously measured values at nearby monitors (parallel consistency check). Values were judged valid if they passed either the sequential or parallel consistency checks. Only four site-days contained values that failed both checks. In all four cases the questionable values did not exceed 6.1 ppm, and deletion from the data was considered unwarranted.[11]

4.10 CREATION OF COMPUTER FILES FOR STATISTICAL ANALYSIS

4.10.1 CALIB-DATA

Table 4-9 lists the data items and format of CALIB-DATA, a general purpose computer file containing the results of the pre and post zero-span checks performed on each PEM; the associated date, temperature, and barometric pressure; and the corrected CO concentration of the breath sample provided by the subject carrying the PEM. The file also contains the average of the pre and post zero-span slope values and the average of the pre and post zero-span intercept values. In addition, columns 53, 54, and 55 of the file contain a three-digit calibration class code (CCC). The CCC is determined by calculating the change in slope and intercept values between the pre and post zero-span checks. Codes are assigned according to Table 4-10. The first digit (column 53) is the slope code, the second digit (column 54) is the intercept code, and the third digit (column 55) is the higher of the two preceding digits. For example, Code 323 indicates the slope class is 3 ($10\% \leq$ slope change $< 15\%$), the intercept class is 2 (1.0 ppm $\leq$ intercept change $<$ 1.5 ppm), and the higher of the two codes is 3.

4.10.2 SAMPLE-DATA

The validated data from the field data sheets required additional processing before statistical analyses could be performed. A special program was developed to perform the following operations on each data set and to merge the resulting transformed data into a single master file labeled SAMPLE-DATA.

1. Each concentration value (columns 26-29) was adjusted according to the equation

$$c_{adj} = (c_{rec} - a_{avg})/b_{avg} \qquad (4\text{-}1)$$

where c_{adj} = the adjusted concentration value

c_{rec} = the recorded concentration value

a_{avg} = the average of the pre and post zero-span intercept values

b_{avg} = the average of the pre and post zero-span slope values.

TABLE 4-9. FORMAT OF CALIB-DATA FILE

Date item	Columns
Date sampled	1-6
Temperature, ^{o}C	7-9
Barometric pressure, mm Hg	10-13
Presample zero concentration, ppm	14,15
Presample span concentration, ppm	16-18
Postsample zero concentration, ppm	19,20
Postsample span concentration, ppm	21-23
Monitor ID	24-29
Presample measured zero concentration, ppm	30,31
Presample measured span concentration, ppm	32-34
Postsample measured zero concentration, ppm	35,36
Postsample measured span concentration, ppm	37-39
Breath CO concentration, ppm	40-42
Calculated average slope	43-47
Calculated average intercept, ppm	48-52
Class code for slope	53
Class code for intercept	54
Highest class code	55

TABLE 4-10. ASSIGNMENT OF SLOPE AND INTERCEPT CODES

Code	Change in slope, percent	Change in intercept, ppm
1	$0 \leq$ change < 5	$0 \leq$ change < 1.0
2	$5 \leq$ change < 10	$1.0 \leq$ change < 1.5
3	$10 \leq$ change < 15	$1.5 \leq$ change < 2.0
4	$15 \leq$ change < 25	$2.0 \leq$ change < 3.0
5	$25 \leq$ change	$3.0 \leq$ change
6	No post-check data	No post-check data

2. Each adjusted concentration was shifted to columns 26-29 of the previous line so that the concentration value was paired with the time the associated activity started rather than the time the activity ended.

3. The sampling date (columns 14-19) was changed to next calendar date on all lines with times occurring after midnight of day sampling starts. Prior to this change, date sampled was the same for all lines in each data set.

4. Whenever A equaled 19, columns 30-56 were filled in with entries from corresponding columns of the most recent line with A ≠ 19. Prior to fill-in, columns 32-56 were blank whenever A equaled 19.

5. The appropriate three-digit calibration class code from the CALIB-DATA file was entered into columns 57-59.

6. A three-digit data quality code was entered into columns 60-62. This code is explained in Section 4.11.

7. The duration (in minutes) of each PEM value was entered into columns 63 and 64.

The SAMPLE-DATA file contains approximately 39,000 lines of data.

4.11 DATA QUALITY CODE

The data quality code (DQC) is a three-digit code that appears in the SAMPLE-DATA file. The DQC, which is the same for all entries of a particular person-day, indicates whether PEM values and activity diary entries are acceptable for certain types of statistical analysis. The first digit indicates whether the PEM values are acceptable for statistical analyses that involve PEM and time data, but not activity diary data (e.g., an analysis of daily maximum 1 hour values). A person-day of PEM data is considered unacceptable if the third digit of the CCC exceeds 3, if maintenance records indicate that the PEM malfunctioned during the sampling period, or if the data set contains less than 18 hours of valid PEM entries. The second digit indicates whether the activity diary data are acceptable for statistical analyses that involve activity diary and time data, but not PEM data (e.g., an analysis of average time spent in certain locations). A person-day of activity diary data is considered unacceptable if the diary was incorrectly filled out or if the data set contains less than 18 hours of diary entries with valid location (B) codes. Invalid location codes include blanks and B = 09 (i.e., location uncertain). The third digit indicates whether or not the PEM and activity diary entries taken together yield at least 18 hours of data that are acceptable for statistical analyses that involve both PEM and activity diary data (e.g., analysis of variation in PEM values with location). A zero appearing in any one of the three digits indicates the associated data are acceptable; a "1" indicates the data are not acceptable.

4.12 THE PROFILE PROGRAM

PEDCo developed the PROFILE program as a means of graphically displaying the data recorded on each field data sheet. Figure 4-5 presents a sample PROFILE output. In the top left-hand corner are listed the PID number, the monitor number, and the start date of the 24-hour period covered by the field data sheet. To the right of this information is a graph of the CO concentration values recorded by the PEM. Each CO value represents the average CO level measured by the PEM between time t_s and time t_{s+1} where s is a sequence number on the field data sheet. These values are rounded to the nearest part per million and plotted above the 15-minute interval that contains t_s.

Below the CO graph are six graphs showing which activity diary codes apply to the subject during each 15-minute interval of the 24-hour period. These graphs correspond to activity diary entries under headings A (activity), B (location), D3 (mode of travel), E1 (attached garage), E2 (gas stove in use), and F (smokers present). Each time "bar" starts with the 15-minute interval containing time t_s and continues through the succeeding 15-minute intervals up to and including the 15-minute interval containing time t_{s+1}.

The PROFILE program provided an additional means of checking the activity diary data for logical inconsistencies and the PEM data for unusually high or low values. PROFILE was also used as a means of summarizing and displaying individual exposures during periods of special significance (e.g., days when fixed-site monitoring data indicate a violation of the National Ambient Air Quality Standard for CO). In addition, PROFILE printouts were furnished to participants who requested their individual exposure results.

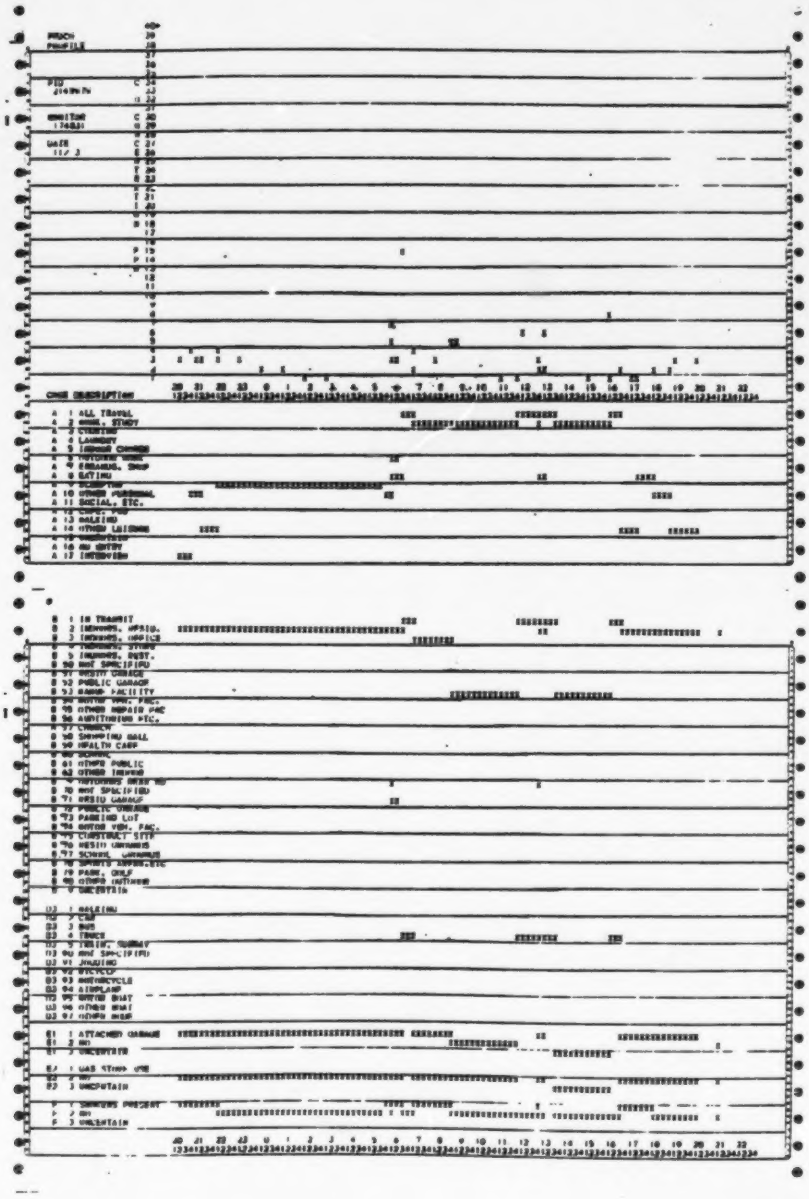


Figure 4-5. Sample output of PROFILE program.

4.13 REFERENCES

1. PEDCo Environmental, Inc. Quality Assurance Project Plan. Carbon Monoxide Exposures in Denver, Colorado. Durham, North Carolina. January 1983.

2. Whitmore, R., S. Jones, and M. Rosenzweig. Final Sampling Report for the Study of Personal CO Exposure. Report No. RTI/2390/02-01F. Research Triangle Institute, Research Triangle Park, North Carolina. September 1983.

3. Bernard, W. F. and J. A. Bowen. Performance and Systems Audit of the Denver Carbon Monoxide Exposure Study. U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory, Research Triangle Park, North Carolina 27711. January 1983.

4. Bowen, J. A. Denver Carbon Monoxide Exposure Study Audit. U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory, Research Triangle Park, North Carolina 27711. March 1983.

5. Rockwell International. Operating Instructions for the Carbon Monoxide Exposure Dosimeter Model COED-1. September 24, 1982.

6. Denver Regional Council of Governments. Denver Metro Census Tract Street Directory. Volume One. Denver, Colorado.

7. Cole's Cross Reference Directory: Greater Denver. Cole's Publications, Lakewood, Colorado. 1983.

8. Memorandum to Gerry Akland, Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency, from Ted Johnson, PEDCo Environmental, Inc., May 9, 1983.

9. The Denver Carbon Monoxide Study: Fixed Station Siting, Data Acquisition, and Quality Assurance. Air Pollution Control Division, Department of Health, State of Colorado. September 1983.

10. Johnson, Ted. A Jump Test for Validating Hourly Average Air Quality Data. Paper No. 82-82.1. Presented at the 75th Annual Meeting of the Air Pollution Control Association, New Orleans, Louisiana, June 1982.

11. Memorandum to Gerry Akland, Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency, from Ted Johnson, PEDCo Environmental, Inc., September 14, 1983.

SECTION 5

LAND USE

One of the goals of the Denver CO study is to assess the relationship between CO exposure and land use. A land use characteristic closely associated with CO levels is traffic density. A particularly useful demographic unit for assessing data related to traffic density is the census tract. The Denver Regional Council of Governments (DRCOG)[1,2] has compiled statistics on the number of persons residing in each census tract and on the number of acres in each census tract that can be characterized as belonging to each of the 13 land uses listed in Table 5-1 and Appendix K. The Bureau of Census has compiled statistics on the number of home-to-work trips that originate and terminate in each census tract.[3] Two traffic density indicators based on these statistics have been developed: residential density (RDEN) and trip density (TDEN).

TABLE 5-1. LAND USE CATEGORIES DEFINED BY THE DENVER REGIONAL COUNCIL OF GOVERNMENTS[1]

Code	Land use
SF	Single family residential
MF	Multi-family residential
MH	Mobile homes
CR	Retail commercial - regional shopping center
C	Commercial (other)
O	Office
PU	Public and semipublic
IT	Industrial, transportation, communication
A	Agriculture
F	Forest
P	Parks and recreation
V	Vacant
S	Special (lakes not in parks)

5.1 RESIDENTIAL DENSITY AND TRIP DENSITY

Residential density is calculated by the equation

$$RDEN = RES/RA, \qquad (5\text{-}1)$$

where RES is the number of census tract residents and RA is the total number of acres falling into three residential land use categories (SF, MF, and MH). Trip density is calculated by the equation

$$TDEN = (WTO + WTI)/(WA + RA) \qquad (5\text{-}2)$$

where WTO is the number of home-to-work trips per day that originate in a census tract, WTI is the number of home-to-work trips per day that terminate in a census tract, and WA is the total number of acres falling into five work-related land use categories (CR, C, O, PU, and IT). Census tracts with higher RDEN and TDEN values would be expected to have higher traffic densities and thus higher CO exposures.

WTO and WTI data were compiled for the census tracts used in the 1970 census. Because many of the 1970 census tracts were subdivided into two or more new census tracts for the 1980 census, WTO and WTI values were not available for many of the 1980 census tracts. In each of these cases, the "parent" 1970 census tract was identified and its TDEN value was calculated.

Appendix L lists values of RES, RA, RDEN, WTO, WTI, WA, and TDEN by 1980 census tract for the census tracts in the Denver study area. Table 5-2 lists descriptive statistics for five of these parameters. An unusually large RA value was recorded for Census Tract 70.31 (3299.7 acres). This census tract has a large number of single-family homes. An unusually large RDEN value (1756.9 persons/acre) was calculated for Census Tract 123.00. Although DRCOG estimates that this census tract contains only 3.2 residential acres, the Bureau of Census reports that 5622 persons resided in this census tract in 1980. This census tract, which is located in the center of Boulder, contains the main campus of the University of Boulder. The median RDEN value for the study area is 11.5 persons per acre.

Unusually large TDEN values of 150.4 and 88.0 trips per acre were estimated for Census Tracts 17.02 and 26.01, respectively. Both census tracts are located in areas of downtown Denver characterized by a high density of multistory office buildings. The median TDEN value for the study area is 4.8 trips per acre.

TABLE 5-2. DESCRIPTIVE STATISTICS FOR SELECTED PARAMETERS RELATED TO LAND USE

Statistic	RES, persons	RA, acres	RDEN, persons/ acre	WA, acres	TDEN, trips/ acre
Minimum	1.0	3.2	0.0	3.6	0.5
Maximum	13936.0	3299.7	1756.9	17013.7	150.4
Mean	4058.4	391.3	20.7	265.2	7.1
Median	3917.0	323.5	11.5	91.7	4.8
Mode	2563.0	a	a	a	2.8
Standard deviation	2079.8	313.3	91.9	1003.4	10.7
Lower quartile	2751.0	200.8	8.5	46.6	2.8
Upper quartile	5234.0	499.4	15.1	199.1	7.2

[a] Not unique.

5.2 SUGGESTED DATA ANALYSIS

The SAMPLE-DATA file contains the census tract location of each PEM value. Consequently, each PEM value can be paired with the appropriate RDEN and TDEN values using the listing in Appendix L. The resulting data set can then be used to statistically assess the relationships between CO exposure and RDEN and between CO exposure and TDEN. Such an analysis had not been attempted at the time of this report.

5.3 REFERENCES

1. Denver Regional Council of Governments. Land Use in the Denver Metropolitan Area. November 1981.
2. Denver Regional Council of Governments. 1980 Population and Households, Denver SMSA. November 1981.
3. Bureau of the Census. Annual Housing Survey, 1976 SMSA Travel-to-Work Summary Statistics (machine-readable file). 1980.

SECTION 6

STUDY RESULTS AND DATA ANALYSIS

Data available for each participant in the Denver study include (1) the data from the various questionnaires; (2) the time each PEM measurement was made, the corresponding CO reading, and the corresponding activity diary codes; and (3) the concentration of CO in each breath sample. In addition, another analysis file contains hourly average CO data from the 15 fixed-site monitors operating during the study. Meteorological and land-use data are also available.

This section summarizes the results of statistical analyses performed on selected data items to determine the distribution of personal CO exposures, the significance of microenvironment and indoor sources on exposure, and the relationship between CO values measured by PEM's and simultaneous values reported by fixed-site monitors. Also included in this section are estimates of the fraction of Denver HU's not on the Donnelley list, frequency distributions of responses to selected questionnaire items, a discussion of the instrument problems experienced during the study, a summary of the calibration results, and suggestions for additional data analysis. The section begins with a discussion of sampling results and response rates.

6.1 SAMPLING RESULTS AND RESPONSE RATES

As indicated in Section 2.1, 425 of the 1000 eligible individuals in the primary and three supplementary samples identified through telephone screening agreed to be interviewed. In addition, 60 of the 139 eligible individuals identified through field screening agreed to be interviewed. Of these 485 eligible individuals, 454 were interviewed successfully and participated in the study.

Of the 100 sampling periods originally planned, 98 were carried out. Two sampling periods (November 11 and 12) were cancelled because of equipment problems. A summary sheet (Figure 4-3) was completed for each of the 98 sampling periods. For each scheduled subject-day, a code was assigned indicating the final status of the subject and the breath sample (Section 4.8). Similarly, data quality codes (DQC's) were assigned to each subject-day indicating the validity of the associated PEM and activity diary data (Section 4.11). Table 6-1 presents the frequency distribution of these codes for the entire study period.

TABLE 6-1. FREQUENCY OF SUMMARY SHEET AND DATA QUALITY CODES

Code type and category	Code	Classification	Number
Summary sheet codes			
Subject	11	Okay	900
	12	Refusal	33
	13	Rescheduled	120
	14	Not eligible	0
	15	Other	41
Breath sample	41	Okay	859
	42	Refusal	1
	43	Leak	30
	44	Illness	1
	45	Other	9
Data quality codes			
PEM data	0	Acceptable	808
	1	Unacceptable	91
Diary data	0	Acceptable	859
	1	Unacceptable	40
PEM + diary data	0	Acceptable	778
	1	Unacceptable	121

A total of 1094 subject-days of participation were scheduled. The 454 individuals who actually participated in the study yielded 900 subject-days; 446 subjects participated in two sampling periods, while 8 subjects participated in only one sampling period. Of the remaining 194 subject-days scheduled, 120 were lost because subjects requested rescheduling, 33 were lost because of last-minute refusals to participate, and 41 were lost for other reasons (e.g., subject missed appointment, interviewer experienced car problems).

Of the 899 subject-days of data contained in the SAMPLE-DATA file, 808 (90%) received DQC's indicating they were judged acceptable for statistical analysis of PEM values. Of the remaining 91 subject-days, 50 received unacceptable DQC's because the third digit of the calibration classification code (CCC) exceeded 3. Section 6.3.1 presents a frequency breakdown of the CCC's. Section 6.3.2 lists the most frequently occurring causes of PEM malfunction.

A total of 859 subject-days of data (96%) received DQC's indicating they were acceptable for statistical analysis of diary entries. In addition, 778 subject-days (87%) were judged acceptable for statistical analyses involving both PEM and diary data.

A total of 859 breath samples were obtained and successfully analyzed for CO content. Thirty samples were lost because of leaks in the sample bag. One subject refused to provide a breath sample, and another was unable to provide a sample because of illness. Nine samples were not obtained for other reasons (e.g., subject could not fill breath bag).

6.2 HOUSING UNITS NOT INCLUDED ON DONNELLEY LIST

RTI supplied to PEDCo a list of 150 HU addresses (15 segments x 10 HU's per segment) randomly selected from the Donnelley list. As Table 2-2 indicates, 130 HU's fall into the 13 segments classified as Stratum 1 (EHUS $\leq$ 1.5) and 20 HU's fall into the 2 segments classified as Stratum 2 (EHUS > 1.5). Using these HU's as start points, field personnel surveyed nearby HU's according to the procedure described in Section 4.1.2. For each start point, the surveyor noted how many HU's were visited before another HU on the Donnelley list was identified.

Table 6-2 lists the 150 start points, the number of missing HU's identified for each start point, and the number of completed field screeners. Note that two start points were found to be outside the segment indicated by the Donnelley list, and 18 start points were not found at all because of incomplete or incorrect Donnelley listings. If these 20 start points are excluded, 119 start points remain in Stratum 1 and 11 start points remain in Stratum 2.

TABLE 6-2. RESULTS OF SURVEY OF HOUSING UNITS NOT INCLUDED ON DONNELLEY LIST

Segment	Case ID of start point	Missing HU's	Completed screeners	Comment
1	9963	3	2	
	9987	0	0	
	10011	1	0	
	11136	0	0	
	11219	1	1	
	12441	3	1	
	12466	0	0	
	13673	0	0	
	13679	4	3	
	13714	0	0	
16	10397	1	1	
	10405	0	0	
	11531	0	0	
	12118	(6)[a]	(5)	Start point outside segment
	12864	1	1	
	12908	0	0	
	13351	1	1	
	13370	-	-	Start point not found
	14082	5	4	
	14606	(2)	(1)	Start point outside segment
22[b]	9921	(9)	(4)	Start point not found
	9974	0	0	
	9996	3	3	
	11171	0	0	
	11187	1	0	
	12104	-	-	Start point not found
	12439	3	2	
	12459	0	0	
	13663	0	0	
	14575	-	-	Start point not found
28	11430	0	0	
	11433	0	0	
	11442	0	0	
	12256	0	0	
	12257	0	0	
	12718	0	0	
	13462	0	0	
	13910	0	0	
	14727	0	0	
	14730	0	0	

(continued)

TABLE 6-2 (continued)

Segment	Case ID of start point	Missing HU's	Completed screeners	Comment
30	10240	0	0	
	10663	0	0	
	11467	0	0	
	11839	0	0	
	11919	4	3	
	12746	0	0	
	13089	0	0	
	13413	0	0	
	13962	0	0	
	14649	0	0	
32	10672	0	0	
	10715	0	0	
	10742	1	0	
	11021	0	0	
	12190	-	-	Start point not found
	13189	1	0	
	13515	0	0	
	14439	0	0	
	14788	0	0	
	14789	0	0	
33	10683	1	0	
	10717	0	0	
	11950	0	0	
	12286	0	0	
	12288	0	0	
	13207	0	0	
	13494	0	0	
	13496	0	0	
	13525	0	0	
	14501	0	0	
37	10738	0	0	
	10992	0	0	
	11935	0	0	
	13215	0	0	
	13482	0	0	
	14400	0	0	
	14496	1	0	
	14502	0	0	
	14751	0	0	
	14760	0	0	

(continued)

TABLE 6-2 (continued)

Segment	Case ID of start point	Missing HU's	Completed screeners	Comment
40	10592	0	0	
	10906	0	0	
	10909	0	0	
	11483	0	0	
	12729	1	0	
	13086	0	0	
	13173	0	0	
	13420	0	0	
	14656	0	0	
	14657	0	0	
43	10610	0	0	
	11853	-	-	Start point not found
	11857	0	0	
	11871	-	-	Start point not found
	11889	-	-	
	11900	-	-	Start point not found
	13147	0	0	
	13155	-	-	Start point not found
	14348	-	-	Start point not found
	14375	0	0	
50	10327	0	0	
	10369	0	0	
	11543	0	0	
	12805	0	0	
	12838	0	0	
	13037	0	0	
	14030	0	0	
	14032	0	0	
	14705	0	0	
	13023	0	0	
63	10937	0	0	
	10939	0	0	
	10941	0	0	
	10942	0	0	
	11108	0	0	
	11123	2	0	
	11258	0	0	
	12230	0	0	
	13442	0	0	
	14695	0	0	

(continued)

TABLE 6-2 (continued)

Segment	Case ID of start point	Missing HU's	Completed screeners	Comment
65	9902	0	0	
	10063	0	0	
	10933	0	0	
	11179	0	0	
	12420	1	1	
	12425	0	0	
	12567	0	0	
	13438	0	0	
	13592	0	0	
	14687	5	3	
86[b]	10459	-	-	Start point not found
	10486	-	-	Start point not found
	11044	0	0	
	11639	-	-	Start point not found
	11664	-	-	Start point not found
	11719	0	0	
	12339	-	-	Start point not found
	12944	7	1	
	14198	0	0	
	14205	-	-	Start point not found
94	10115	0	0	
	10153	0	0	
	11316	0	0	
	11332	-	-	Start point not found
	12609	0	0	
	12650	0	0	
	13306	0	0	
	13799	0	0	
	13809	0	0	
	13894	-	-	Start point not found

[a] Parentheses indicate values pertaining to start points found to be outside designated segment or not found at all.

[b] Segments 22 and 86 are in Stratum 2; all other segments are in Stratum 1.

The counting of non-Donnelley HU's at each start point can be considered a statistical trial. In trial i, x_i non-Donnelley HU's are observed. If the actual fraction of non-Donnelley HU's in the parent population is 1-p, then x_i follows a geometric distribution with

$$\text{mean} = \frac{1-p}{p} \tag{6-1}$$

and

$$\text{variance} = \frac{1-p}{p^2} \quad . \tag{6-2}$$

The maximum likelihood estimate of p is

$$\hat{p} = \frac{1}{1 + \bar{x}} \tag{6-2}$$

where

$$\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i \quad . \tag{6-3}$$

For $n > 10$, the quantity

$$z = [np\bar{x} - n(1-p)]/\sqrt{n(1-p)} \tag{6-4}$$

is approximately normally distributed with mean 0 and variance 1. Thus, there is a probability of $1-\alpha$ that

$$\frac{-z^2 + 2n\bar{x} + 2n - w}{(2n)(\bar{x}+1)^2} < p < \frac{-z^2 + 2n\bar{x} + 2n + w}{(2n)(\bar{x}+1)^2} \tag{6-5}$$

where

$$w = z\sqrt{4n\bar{x} + 4n\bar{x}^2 + z^2} \tag{6-6}$$

and the area under the standard normal curve from $-z$ to z is $1-\alpha$.

Table 6-2 indicates that 37 missing HU's were counted in the 119 valid trials using Stratum 1 startpoints. Consequently, $n_1 = 119$ and $\bar{x} = 37/119 = 0.311$. The 95 percent confidence interval ($z = 1.960$) for the p value of stratum 1 is

$$0.705 < p_1 < 0.840$$

and $\hat{p}_1 = 0.763$. Thus, it is estimated that 76.3 percent of HU's in sections of the study area where EHUS $\leq$ 1.5 are on the Donnelley list and 23.7 percent are not.

Similarly, Table 6-2 indicates that 14 missing HU's were counted in the 11 valid trials using Stratum 2 start points. Using $n_2 = 11$ and $\bar{x} = 14/11 =$

1.273, the 95 percent confidence interval for the p value of Stratum 2 is calculated to be

$$0.276 < p_2 < 0.671$$

and $\hat{p}_2 = 0.440$. Thus, it is estimated that 44.0 percent of HU's in sections of Denver where EHUS > 1.5 are on the Donnelley list and 56.0 percent are not.

The sampling weights $[W_4(i)]$ for Stratum 1 and Stratum 2 are 92/13 and 7/2, respectively. Consequently, the Donnelley list coverage for the entire study area can be estimated as

$$\hat{p} = [(92/13)(\hat{p}_1) + (7/2)(\hat{p}_2)]/[(92/13) + (7/2)] \qquad (6\text{-}7)$$

to yield

$$\hat{p} = 0.656 \ .$$

This result indicates that 65.6 percent of all HU's in the Denver study area were included in the Donnelley list.

6.3 INSTRUMENT PERFORMANCE

6.3.1 Results of Quality Assurance Activities

The quality assurance (QA) procedures and results for the fixed-site monitors are provided in a report by the State of Colorado.[1] The QA procedures applied to PEM's are described in Section 4.5 of this report. As discussed below, the results of these procedures provide indications of the overall linearity, accuracy, and precision of the PEM's.

Linearity--

Multipoint calibrations were performed on each PEM prior to its first use in the field and at the completion of field sampling in March 1983. A PEM was also recalibrated following any change to the MAGUS data system. In addition, PEM's were recalibrated whenever a span shift greater than ±10 percent occurred based on daily zero/span checks. Span shifts resulted in some 85 recalibrations. Table 6-3 list the total number of multipoint calibrations performed on each PEM. The average number per PEM was 5.4.

TABLE 6-3. PEM MULTIPOINT CALIBRATION FREQUENCY

PEM ID	Frequency
174799	6
174803	5
174808	7
174809	7
174811	5
174812	5
174816	6
174818	6
174820	5
174821	8
174822	7
174824	8
174827	6
174830	9
174831	6
174832	8
174835	7
174836	2
174837	5
174960	3
179704	2
179783	2
179854	5
179858	4
179861	9
179862	5
179863	6
179938	6
179943	6
179944	4
179950	2
179954	2
Total	174

The initial multipoint calibrations performed during October revea potential nonlinearity problem in the low concentration portion of the operating range. This nonlinearity was the result of an imbalance betwee General Electric (GE) sensor outputs and the output of the Magus data subs Figure 6-1 graphically presents the response of an improperly balanced PEM. This nonlinearity was reduced significantly by the following balancing proc dure developed by PEDCo. While zero air was being injected into a PEM, the output from the GE sensor was monitored via the PEM's recorder jack using a digital voltmeter (accuracy = ± 0.1 mVDC). The output of the GE sensor is 1 mVDC per ppm, CO. This output was compared with the Magus output displayed on the PEM's LCD while in the log mode. The sensor's zero trim pot was adjuste counterclockwise until zero voltage was indicated on the voltmeter. After the zero voltage level had stabilized, the Magus data subsystem was balanced to match the GE sensor output by adjusting the zero trim pot on the Magus digital board. This process was repeated using a span gas while the corresponding span trim pots were adjusted. Both processes were repeated until acceptable reproducibility or agreement between the two systems were reached.

Once a PEM was balanced properly, the nonlinearity problem at low concentrations appeared to improve, but it did not disappear. Some of the low concentration error may have been due to nonlinearity in either the sensor or the data subsystem. In an effort to quantify this nonlinearity, 10 properly balanced PEM's were subjected to a 15-point calibration. Particular emphasis was placed on the concentration range of zero to 25 ppm. Table 6-4 summarizes the results of this calibration. Figure 6-2 is a plot of the actual concentrations vs. the average of all 10 PEM responses.

Accuracy--

As part of the daily zero-span procedures described in Section 4.5, a straight line was fit to the pre zero-span results for each PEM and its slope and intercept were determined. The slope and intercept were similarly determined for a line fit to the post zero-span results. As described in Section 4.10, the slope and intercept values for each PEM-day of sampling were used to adjust the PEM readings recorded on the field data sheet and to determine calibration class codes.

Table 6-5 presents frequencies of the slope and intercept codes. The distribution of these codes provides a general indication of PEM measurement

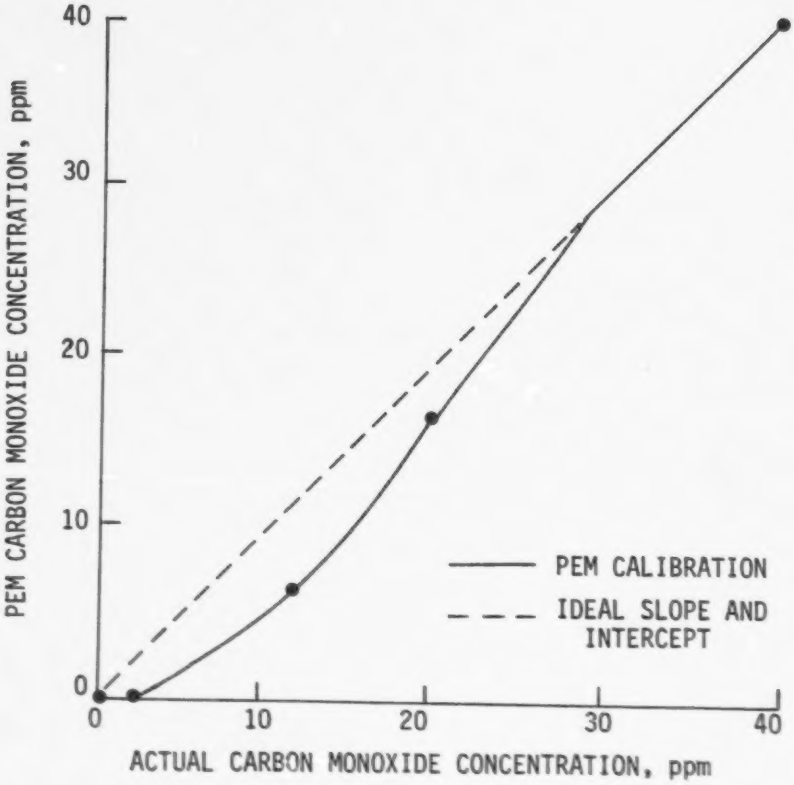


Figure 6-1. Sample calibration plot of unbalanced PEM.

TABLE 6-4. FIFTEEN-POINT CALIBRATION SUMMARY

Sampler ID	Calibration concentrations (CO, ppm)															
	0.0	1.8	2.8	3.5	5.1	5.7	8.3	8.5	10.6	12.2	14.2	18.4	21.0	23.5	40.8	
	PEM integrated values (CO, ppm)															Corr.
174808	0.6	2.1	2.8	3.5	5.0	5.5	8.2	8.4	10.5	12.1	14.1	18.4	21.1	23.6	41.1	0.9998
174809	0.8	2.0	2.9	3.5	4.9	5.4	8.2	8.4	10.4	12.1	14.1	18.2	20.8	23.3	40.4	0.9998
174816	0.3	1.6	2.6	3.2	4.6	5.2	7.9	8.1	10.1	11.9	13.8	18.0	20.7	23.2	40.7	0.9998
174818	0.2	1.5	2.4	3.1	4.6	5.1	7.9	8.1	10.1	12.0	14.0	18.3	21.0	23.7	41.3	0.9998
174821	0.2	1.6	2.4	3.1	4.6	5.1	7.9	8.1	10.2	11.9	13.8	17.7	20.9	23.1	40.9	0.9998
174824	0.9	2.4	3.2	3.8	5.3	5.8	8.5	8.7	10.8	12.4	14.5	18.7	21.3	24.0	41.5	0.9998
174832	0.6	2.0	2.9	3.6	5.1	5.6	8.4	8.5	10.7	12.5	14.4	18.7	21.4	24.0	41.5	0.9996
174960	0.3	1.6	2.4	3.0	4.4	5.0	7.6	8.1	9.7	11.6	13.6	17.9	21.0	23.2	41.0	0.9995
179858	0.1	1.6	2.5	3.1	4.6	5.1	7.8	7.9	10.1	11.8	13.8	18.1	20.6	23.4	40.7	0.9998
179954	0.1	1.6	2.5	3.1	4.6	5.2	7.7	8.0	10.1	11.8	13.8	18.1	20.8	23.4	40.9	0.9998
Mean	0.4	1.8	2.7	3.3	4.8	5.3	8.0	8.2	10.3	12.0	14.0	18.2	21.0	23.5	41.0	
Mean percent diff.		0	-5.0	-5.7	-6.5	-7.0	-3.2	-3.2	-3.1	-1.6	-1.5	-1.0	-0.3	-0.1	0.5	
Std. dev., percent diff.		16.8	9.9	7.9	5.6	4.6	3.8	3.0	3.1	2.3	2.0	1.8	1.2	1.4	0.9	

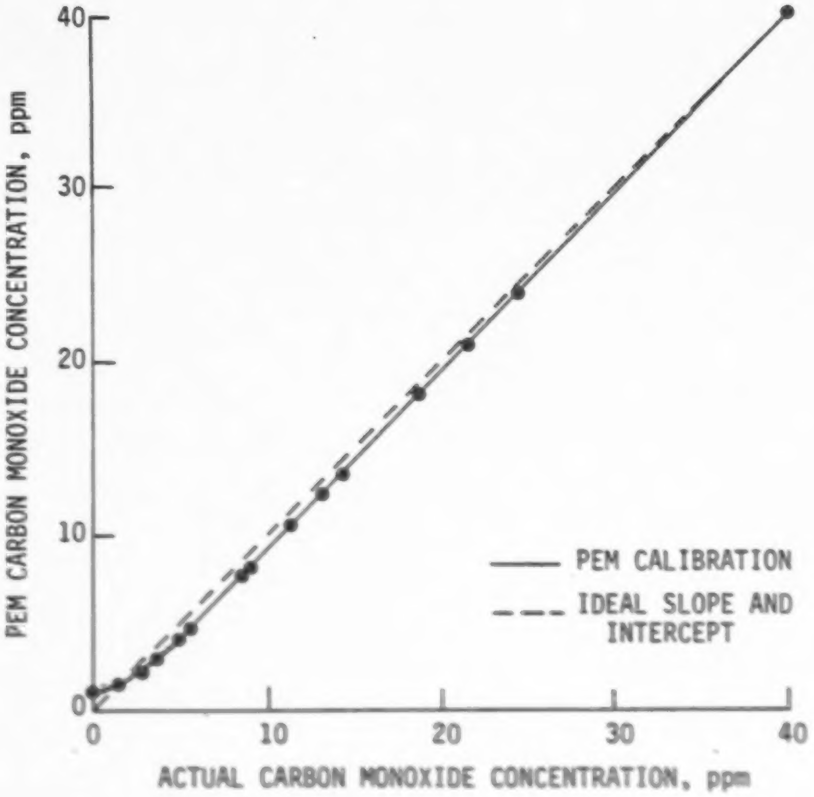


Figure 6-2. Fifteen-point calibration plot of average PEM values.

TABLE 6-5. FREQUENCY OF SINGLE-DIGIT SLOPE AND INTERCEPT CODES

Code	Change in slope, percent	Freq.	Change in intercept, ppm	Freq.
1	$0 \leq$ change < 5	833	$0 \leq$ change < 1.0	524
2	$5 \leq$ change < 10	34	$1.0 \leq$ change < 1.5	286
3	$10 \leq$ change < 15	5	$1.5 \leq$ change < 2.0	43
4	$15 \leq$ change < 25	3	$2.0 \leq$ change < 3.0	13
5	$25 \leq$ change	1	$3.0 \leq$ change	10
6	No post-check data	23	No post-check data	23
	Total	899	Total	899

TABLE 6-6. FREQUENCY OF THREE-DIGIT CALIBRATION CLASSIFICATION CODES

Three-digit CCC	Frequency	Percentage of total
111	510	56.7
122	11	1.2
133	2	0.2
144	1	0.1
212	267	29.7
222	16	1.8
233	3	0.3
313	34	3.8
323	6	0.7
344	2	0.2
355	1	0.1
414	12	1.3
424	1	0.1
515	10	1.1
666	23	2.6
Total	899	100.0

accuracy. Of the 899 PEM days, 833 (92.7%) had less than 5 percent change in slope, 867 (96.4%) had less than 10 percent change in slope, 524 (58.3%) had less than 1.0 ppm change in intercept, and 853 (94.9%) had less than 2.0 ppm change in intercept. Table 6-6 lists frequencies for the three-digit CCC's. The most frequently occurring CCC is 111. The third digit is 1 in 510 (56.7%) of the cases, 2 in 294 (32.7%) of the cases, 3 in 45 (5.0%) of the cases, 4 in 16 (1.8%) of the cases, 5 in 11 (1.2%) of the cases, and 6 in 23 (2.6%) of the cases. A summary of the daily pre and post zero-span data is presented in Appendix M.

Post zero-span checks indicated a median decrease of 3.8 percent in the sensitivity of the PEM's over the 24-hour sampling periods. In approximately 85 percent of the sampling periods, the PEM span dropped off and the recorded PEM values were less than the actual concentrations. This loss of sensitivity may have been a function of 1) low ambient temperature during the sampling period, 2) low pump flow during sampling, and/or 3) normal span drift. Overall, the decrease in sensitivity did not present any major problems; however, it should not be overlooked in future studies.

Precision--

PEM precision during normal use was evaluated by having a subject or technician carry two monitors through a 24-hour sampling period. The mean percent difference and the standard deviation of the percent differences were then calculated for paired observations where both values were greater than or equal to 1 ppm. Analysis of 193 pairs of values taken throughout the study resulted in a mean difference of 5.0 percent and a standard deviation of 14.2 percent. These results suggest a single hourly average observation of 10 ppm would be between 7.7 ppm and 13.3 ppm 95 percent of the time.

Intermethod precision was determined by comparing the PEM with the reference or equivalent NDIR method used by the State and local agencies for compliance monitoring. These comparisons, which were performed by the Air Pollution Control Division of the Colorado Department of Health, were made by attaching the inlet sample line of the PEM to the manifold supplying sample ambient air to one of the CO study's 1 fixed-site monitoring stations.[1] Differences between the PEM and fixed-site values were calculated using only data where both monitors recorded hourly values greater than or equal to 1 ppm and the measurements were made during the first 24-hours of each comparison (to minimize the effect of battery discharge). The mean difference of the resulting 85 pairs of values was 8.3 percent (fixed site being higher); the standard deviation was 22 percent.

Independent Audits--

The Quality Assurance Division, Environmental Monitoring Systems Laboratory, EPA, performed two systems and performance audits of the monitoring program.[2,3] The first audit was conducted at the start of the project, November 15-21, 1982. The second was conducted February 21-25, 1983, near the end of the study. Results of both audits indicated that the audited PEM's were within ±10 percent of the audit gases and that the fixed site monitors were all within ±5 percent of the audit gases.

Recommendations--

PEDCo offers two recommendations for future studies. First, the balance check described above should be incorporated as part of any multipoint calibrations that are performed. Secondly, the PEM data subsystem should be changed to permit the storing of negative concentration values. If this is not feasible, then consideration should be given to a positive offset of the PEM zero by approximately 1 ppm.

6.3.2 Instrument Problems

Two sets of PEM's were used during the course of the Denver CO Study. The primary set contained 26 PEM's that were used throughout the study. A supplementary set of six PEM's were put into operation on February 9, 1983, and were used during the remainder of the study. These six PEM's had been used previously by RTI as part of a parallel study of CO exposure in Washington, D.C., which ended February 7, 1983. Consequently, each of the 32 PEM's used in the study experienced several months of constant use.

A log was maintained on each PEM, which listed all instances during the Denver study in which the PEM failed a zero-span check, all other instrument failures that occurred (whether or not data were affected), and any other situations in which nonroutine servicing was performed. Table N-1 in Appendix N lists all malfunctions recorded in these logs. Table 6-7 lists the 11 PEM malfunctions that occurred most frequently. These malfunctions are discussed in detail in Appendix N.

TABLE 6-7. PEM MALFUNCTIONS WHICH OCCURRED MOST FREQUENTLY DURING DENVER CO STUDY

PEM malfunction	Number of occurrences
Low flow rate caused by clogged pump	42
PEM failed zero-span check	31
PEM switched to ALOG mode	25
Lockup (no change in time displayed and no data stored)	22
Low pump battery voltage	14
Low MAGUS battery voltage	14
Known or suspected programming error	7
PEM switched to SCLR mode	6
Broken bias battery strap	6
Loose Amphenol plug	5
Bad solder joint	5

6.4 FREQUENCY DISTRIBUTION OF SELECTED QUESTIONNAIRE RESPONSES

The study questionnaire (Appendix C) was successfully administered to 448 of the 454 study participants. As described in Section 4.10, PEDCo developed a computer file listing PID and responses to selected data items on the study questionnaire. Table 6-8 lists the frequency of responses to multiple-choice data items; Table 6-9 lists the frequency of responses to fill-in data items (excluding occupation); and Table 6-10 lists occupation frequencies according to the categories defined by the U.S. Bureau of Census. Table 6-11, which was developed from Table 6-10, lists occupation frequencies for general occupational groups defined by the U.S. Bureau of Census.

6.5 CO DATA REPORTED BY FIXED-SITE MONITORS

Section 3.8 described the 15 fixed-site monitors which operated in the Denver metropolitan area during the period of the study. Table 6-12 lists location coordinates of each site, its SAROAD code, the map code used in Figure 3-3, and a three-digit code used by PEDCo in various statistical analyses. A computer file was created which provides the hourly average

TABLE 6-8. FREQUENCY OF RESPONSES FOR SELECTED DATA ITEMS ON STUDY QUESTIONNAIRE

Data item[a]	Response	Number	Percent
1. Housing type	Blank	1	0.2
	1: one family detached house	360	80.4
	2: one family attached house	23	5.1
	3: duplex	10	2.2
	4: apartment	54	12.1
	5: mobile home or trailer	0	0
	6: rented room	0	0
	7: boat, van, etc.	0	0
3d. Packs of cigarettes smoked per week by other household members[b]	Blank (no smokers in residence)	334	74.6
	1: less than 1 pack	49	10.9
	2: 1 to 4 packs	39	8.7
	3: 5 to 7 packs	14	3.1
	4: 8 or more packs	12	2.7
4a. Fireplace[b]	Blank	1	0.2
	1: used and vented	176	39.3
	2: used, not vented	6	1.3
	3: not used	265	59.2
4b. Wood stove[b]	Blank	1	0.2
	1: used and vented	41	9.2
	2: used, not vented	4	0.9
	3: not used	402	89.7
4c. Gas furnace[b]	Blank	1	0.2
	1: used and vented	353	78.8
	2: used, not vented	16	3.6
	3: not used	78	17.4
4d. Gas cooking stove[b]	Blank	1	0.2
	1: used and vented	42	9.4
	2: used, not vented	64	14.3
	3: not used	341	76.1
4e. Gas hot water[b]	Blank	2	0.4
	1: used and vented	331	73.9
	2: used, not vented	38	8.5
	3: not used	77	17.2
4f. Gas clothes dryer[b]	Blank	1	0.2
	1: used and vented	79	17.6
	2: used, not vented	12	2.7
	3: not used	356	79.5

(continued)

TABLE 6-8 (continued)

Data item[a]	Response	Number	Percent
4g. Gas or kerosene space heater[b]	Blank	1	0.2
	1: used and vented	6	1.3
	2: used, not vented	32	7.1
	3: not used	409	91.3
4h. Other gas appliance[b]	3: not specified by coder (error)	1	-
	4: space heater	1	-
	5: wall heater	2	-
	6: gas log	1	-
5a. Storm windows[b]	Blank	1	0.2
	1: yes	273	60.9
	2: no	170	37.9
	3: don't know	4	0.9
5b. Storm doors[b]	Blank	1	0.2
	1: yes	281	62.7
	2: no	157	35.0
	3: don't know	9	2.0
5c. Extra insulation[b]	Blank	1	0.2
	1: yes	211	47.2
	2: no	161	35.9
	3: don't know	75	16.7
5d. Special dampers in stove or fireplace[b]	Blank	2	0.4
	1: yes	74	16.5
	2: no	287	64.1
	3: don't know	85	19.0
5e. Other energy-saving device[b]	4: glass fireplace doors	4	-
	5: aluminum siding	3	-
	6: solar hot water heater	11	-
	7: hot water tank	1	-
	8: electric ignition on gas stove or dryer	3	-
	9: heatolator	1	-
	0: automatic damper on furnace	2	-
	A: fireplace insert	3	-
	B: computerized thermostat	11	-
	C: H_2O restrictors in drains	1	-
	D: solar panels	0	-
	E: dryer vent (to inside)	2	-
	F: electric monitor	1	-
	G: hot H_2O restrictor	1	-
	H: steel siding	1	-
	I: plastic window covers	5	-

(continued)

TABLE 6-8 (continued)

Data item[a]	Response	Number	Percent
	J: solar heating	1	-
	K: insulated curtains	2	-
	L: weather stripping	1	-
	M: hot H_2O heater blanket	2	-
	N: flue damper or gas furnace	2	-
	P: caulking	4	-
	Q: foam over windows	1	-
	R: Dencor System for electric heat	1	-
	S: blown insulation in walls	1	-
	T: energy saving appliance	4	-
	U: window quilts	1	-
	V: storm windows	1	-
	W: wood stove	1	-
	X: sky lights	1	-
6a. Attic fan[b]	Blank	1	0.2
	1: yes	65	14.5
	2: no	382	85.3
6b. Window fan[b]	Blank	1	0.2
	1: yes	58	12.9
	2: no	389	86.8
6c. Other fan[b]	Blank	4	0.9
	1: yes	176	39.3
	2: no	268	59.8
6d. Specify other fan[b]	3: portable room fans	52	-
	4: vent fan (exhaust)	72	-
	5: ceiling fan	25	-
	6: furnace fan	4	-
	7: oscillating fan	12	-
	8: humidifier	1	-
	9: solar fan	1	-
	0: portable cooler	2	-
	A: stationary room fan	3	-
	B: fireplace blower fan	1	-
	C: evaporative cooler	1	-
	D: light fan	1	-
	E: portable swamp cooler	1	-
7. Heating system[b]	Blank	2	0.4
	1: steam or hot water system	71	15.8
	2: central warm air furnace with ducts to individual rooms, or central heat pump (forced air)	341	76.1

(continued)

TABLE 6-8 (continued)

Data item[a]	Response	Number	Percent
	3: built-in electric units, permanently installed in wall, ceiling, or baseboard	5	1.1
	4: floor, wall, or unvented furnace	4	0.9
	5: circulating, radiant, or room heaters, WITH flue or vent, burning gas, oil, or kerosene	5	1.1
	6: circulating radiant, or room heaters (not portable) WITHOUT flue or vent, burning gas, oil, or kerosene	2	0.4
	7: portable room heaters of any kind	1	0.2
	8: fireplace(s) or stove(s) burning coal, wood, or coke	13	2.9
	10: no heating equipment	0	0
	11: gravity gas	3	0.7
	94: don't know	1	0.2
8. Air conditioner in use[b]	Blank	2	0.4
	1: central	62	13.8
	2: window	45	10.0
	3: no	339	75.7
10a. Bus garage[c]	Blank	5	1.1
	1: yes	4	0.9
	2: no	439	98.0
10b. Heavy vehicle[c] maintenance or depot	Blank	6	1.3
	1: yes	18	4.0
	2: no	424	94.6
10c. Site of open burning[c]	Blank	6	1.3
	1: yes	0	0
	2: no	442	98.7
10d. Electricity or steam plant[c]	Blank	5	1.1
	1: yes	2	0.4
	2: no	441	98.4
10e. Manufacturing plant with heavy emissions[c]	Blank	6	1.3
	1: yes	4	0.9
	2: no	438	97.8

(continued)

TABLE 6-8 (continued)

Data item[a]	Response	Number	Percent
22. Type of enclosed work area (EWA)[d]	Blank	132	e
	1: office or other small area, work alone	52	16.5
	2: office or other small area shared with other people	122	38.6
	3: large area (factory floor, laboratory, store, etc.), work alone	8	2.5
	4: large area shared with other people	89	28.2
	5: circulate throughout building	21	6.6
	7: outdoors	1	0.3
	8: garage - service station	3	0.9
	9: house	2	0.6
	10: car (delivery driver)	2	0.6
	11: office w/attached auto center	1	0.3
	12: classroom shared w/people	6	1.9
	13: large garage	1	0.3
	14: new houses	1	0.3
	15: individual homes	5	1.6
	16: truck	1	0.3
	17: indoor pool	1	0.3
24. Air-conditioning in EWA	Blank	133	e
	1: central	198	62.9
	2: window unit(s)	11	3.5
	3: no	106	33.7
25. Fan in EWA	Blank	133	e
	1: window	7	2.2
	2: other	95	30.2
	3: window + other	3	1.0
	4: no	210	66.7
27. Work place heating system	Blank	132	e
	01: steam or hot water system	70	22.2
	02: central warm air furnace with ducts to individual rooms, or central heat pump (forced air)	162	51.3
	03: built-in electric units, permanently installed in wall, ceiling, or baseboard	21	6.6
	04: floor, wall, or unvented furnace	0	0

(continued)

TABLE 6-8 (continued)

Data item[a]	Response	Number	Percent
	05: circulating, radiant, or room heaters, WITH flue or vent, burning gas, oil, or kerosene	9	2.8
	06: circulating radiant, or room heaters (not portable) WITHOUT flue or vent, burning gas, oil, or kerosene	6	1.9
	07: portable room heaters of any kind	2	0.6
	08: fireplace or stove burning coal, wood, or coke	0	0
	10: no heating equipment/car heater[f]	4	1.3
	11: forced air w/o ducts	1	0.3
	12: heat radiated from computer and electrical equipment	1	0.3
	13: hot air recirculated from compressor room	1	0.3
	14: gas burning, hanging type	2	0.6
	15: heat from kitchen equipment	1	0.3
	16: boiler	1	0.3
	40: not specified by coder	1	0.3
	94: don't know	34	10.8
28a. Bus garage[g]	Blank	126	e
	1: yes	17	5.3
	2: no	305	94.7
28b. Heavy vehicle maintenance or depot[g]	Blank	126	e
	1: yes	45	14.0
	2: no	277	86.0
28c. Site of open burning[g]	Blank	127	e
	1: yes	2	0.6
	2: no	319	99.4
28d. Electricity or steam plant[g]	Blank	130	e
	1: yes	20	6.3
	2: no	298	93.7
28e. Manufacturing plant with heavy emissions[g]	Blank	136	e
	1: yes	13	4.2
	2: no	299	95.8

(continued)

TABLE 6-8 (continued)

Data item[a]	Response	Number	Percent
35. Sex	Blank	1	[e]
	0: [h]	1	[e]
	1: male	166	37.2
	2: female	280	62.8
B. Construction of residence	Blank	2	0.4
	1: one story house/duplex	149	33.3
	2: two or more story house/duplex	230	51.3
	3: split level	66	14.7
	4: garden type apartment/ condominium	1	0.2
	5: high rise apartment/condominium	0	0
	6: not specified by coder	0	0

---

[a] Abbreviated form, see Study Questionnaire for exact wording of question.

[b] In residence.

[c] Within three blocks of residence.

[d] Enclosed work area in which majority of work takes place.

[e] Response not considered in calculating percentages.

[f] Same code used for more than one response (error).

[g] Within three blocks of work.

[h] Prohibited code (error).

TABLE 6-9. SUMMARY STATISTICS FOR SELECTED DATA ITEMS FROM STUDY QUESTIONNAIRE

Data item	Blanks	Non-blanks	Minimum	Maximum	Mean	Standard deviation	Percentiles				
							10	25	50	75	90
2. Living area, ft^2	39	409	150	22,000	1704	1579	750	1000	1425	2056	2600
18. Model year of auto	75	373	51	83	76	5	70	74	78	80	81
23. Area of EWA, ft^2	153	295	15	360,000	6625	26,438	120	225	667	2450	10,800
36. Age, years	1	447	18	70	40	14	25	29	37	51	61

TABLE 6-10. NUMBER OF STUDY PARTICIPANTS IN OCCUPATIONAL CATEGORIES USED BY U.S. BUREAU OF CENSUS

Code	Occupational category	Number
005	Administrators and officials, public administration	2
007	Financial managers	2
008	Personnel and labor relations managers	1
009	Purchasing managers	1
013	Managers, marketing, advertising, and public relations	4
014	Administrators, education	2
015	Managers, medicine and health	5
016	Managers, properties and real estate	3
019	Managers and administrators, not elsewhere coded (n.e.c.)	12
023	Accountants and auditors	6
025	Other financial officers	2
026	Management analysts	2
027	Personnel, training, and labor relations specialists	1
029	Buyers, wholesale and retail, except farm products	1
037	Management-related occupations, n.e.c.	3
055	Electrical and electronic engineers	2
059	Engineers, n.e.c.	2
064	Computer systems analysts and scientists	2
065	Operations and systems researchers and analysts	1
067	Statistician	1
075	Geologists and geodesists	4
077	Agricultural and food scientists	1
078	Biological and life scientists	1
084	Physicians	6
095	Registered nurses	10
096	Pharmacists	3
097	Dietitians	1
124	Political science teachers	1
137	Art, drama, and music teachers	1
138	Physical education teachers	3
139	Education teachers	2
143	English teachers	1
148	Trade and industrial teachers	1
155	Teachers, prekindergarten and kindergarten	2
156	Teachers, elementary school	16
157	Teachers, secondary school	2
158	Teachers, special education	1
159	Teachers, n.e.c.	6
163	Counselors, educational and vocational	4

(continued)

TABLE 6-10 (continued)

Code	Occupational category	Number
164	Librarians	2
173	Urban planners	1
174	Social workers	3
176	Clergy	1
178	Lawyers	7
185	Designers	2
186	Musicians and composers	1
189	Photographers	1
195	Editors and reporters	2
198	Announcers	1
203	Clinical lab technologists and technicians	2
207	Licensed practical nurses	3
208	Health technologists and technicians, n.e.c.	1
213	Electrical and electronic technicians	3
216	Engineering technicians, n.e.c.	2
228	Broadcast equipment operators	1
229	Computer programmers	4
235	Technicians, n.e.c.	1
243	Supervisors and proprietors, sales occupations	4
253	Insurance sales occupations	3
254	Real estate sales occupations	2
255	Securities and financial services sales occupations	1
257	Sales occupations, other business services	1
259	Sales representatives, mining, manufacturing and wholesale	3
263	Sales workers, motor vehicles and boats	1
268	Sales workers, hardware and building supplies	1
274	Sales workers, other commodities	7
275	Sales counter clerks	1
276	Cashiers	1
277	Street and door-to-door sales workers	1
278	News vendors	1
303	Supervisors, general office	1
309	Peripheral equipment operators	2
313	Secretaries	13
315	Typists	7

(continued)

TABLE 6-10 (continued)

Code	Occupational category	Number
319	Receptionists	1
323	Information clerks, n.e.c.	1
336	Records clerks	3
[illegible]7	Bookkeepers, accounting, and auditing clerks	3
[illegible]4	Postal clerks, except mail carriers	1
357	Messengers	1
375	Insurance adjusters, examiners, and investigators	1
376	Investigators and adjusters, except insurance	2
377	Eligibility clerks, social welfare	1
378	Bill and account collectors	1
379	General office clerks	14
385	Data-entry keyers	1
406	Child care workers, private household	1
418	Police detectives, public service	1
426	Guards and police, except public service	2
427	Protective services occupations, n.e.c.	2
434	Bartenders	1
435	Waiters and waitresses	2
436	Cooks, except short order	3
444	Miscellaneous food preparation occupations	1
446	Health aides, except nursing	1
447	Nursing aides, orderlies, and attendants	2
449	Maids and housemen	4
453	Janitors and cleaners	3
467	Homemaker	90
468	Child care workers	2
495	Forestry workers, except logging	1
503	Supervisors, mechanics, and repairers	1
506	Auto mechanic apprentices	1
507	Bus, truck, and stationary engine mechanics	1
508	Aircraft engine mechanics	1
509	Small engine repairers	1
514	Auto body and related repairers	1
516	Heavy equipment mechanics	1

(continued)

TA[illegible] 10 (continued)

Cod[illegible]	Occupational category	Number
518	Industrial machinery repairers	1
529	Telephone installers and repairers	2
534	Heating, air conditioning, and refrigeration mechanics	1
535	Camera, watch, and musical instrument repairers	1
536	Locksmiths and safe repairers	1
539	Mechanical controls and valve repairers	1
555	Supervisors, electricians and power transmission installers	1
558	Supervisors, construction occupations, n.e.c.	2
567	Carpenters	4
577	Electrical power installers and repairers	1
588	Concrete and terrazzo finishers	1
599	Construction trades, n.e.c.	1
617	Mining occupations, n.e.c.	1
633	Supervisors, production occupations	2
637	Machinists	1
644	Precision grinders, fitters, and tool sharpeners	1
657	Cabinet makers and bench carpenters	1
677	Optical goods workers	1
678	Dental lab and medical appliance technicians	1
696	Stationary engineers	1
734	Printing machine operators	1
736	Typesetters and compositors	1
743	Textile cutting machine operators	1
744	Textile sewing machine operators	1
763	Roasting and baking machine operators, food	1
765	Folding machine operators	1
774	Photographic process machine operators	1
777	Miscellaneous machine operators, n.e.c.	1
779	Machine operators, not specified	1
787	Hand molding, casting, and forming occupations	1
796	Production inspectors, checkers, and examiners	1
804	Truck drivers, heavy	2
805	Truck drivers, light	4
856	Industrial truck and tractor equipment operators	1

(continued)

TABLE 6-10 (continued)

Code	Occupational category	Number
869	Construction laborers	3
877	Stock handlers and baggers	2
885	Garage and service station related occupations	2
888	Hand packers and packagers	1
889	Laborers, except construction	1
998[a]	Not employed	12
999[a]	Retired	20
Blank		1
	Total	448

[a] Unofficial code used by PEDCo.

TABLE 6-11. NUMBER OF STUDY PARTICIPANTS IN OCCUPATIONAL GROUPS USED BY U.S. BUREAU OF CENSUS

Occupational group	Codes	Number
1. Executive, administrative, and managerial occupations	003-037	47
2. Professional specialty occupations	043-199	95
3. Technicians and related support occupations	203-235	17
4. Sales occupations	243-285	27
5. Administrative support occupations, including clerical	303-389	53
6. Private household occupations	403-407	1
7. Protective service occupations	413-427	5
8. Service occupations,[a] except 6 and 7	433-469	109
9. Farming, forestry, and fishing occupations	473-499	1
10. Precision production, craft, and repair occupations	503-699	33
11. Machine operators, assemblers, and inspectors	703-799	11
12. Transportation and material moving occupations	803-859	7
13. Handling, equipment cleaners, helpers, and laborers	863-889	9

[a] Includes homemakers (code 467).

TABLE 6-12. LOCATIONS OF FIXED-SITE MONITORS

Map code[a]	SAROAD code	Three-digit code	Latitude	Longitude
A	060580002F01	002	39.7511	104.9872
B	060580014F01	014	39.7526	105.0349
C	060580013F01	013	39.7325	104.9348
D	062080821F05	821	39.7171	104.9841
E	062080822F05	822	39.6891	105.0456
F	062080820F05	820	39.7645	105.0061
G	062080823F05	823	39.6483	104.9201
H	062080825F05	825	39.6084	104.9136
I	062080818F05	818	39.7665	104.9666
J	062080819F05	819	39.7347	105.0034
K	060140002F01	AUR	39.7169	104.8414
L	060120002F01	ARV	39.8006	105.0992
M	060080002F01	HIG	39.5661	104.9580
N	062080824F05	824	39.6467	104.9944
O	062080817F05	817	39.7639	104.8944
-	Composite	AVG	-	-

[a] Figure 3-3.

values reported by all 15 fixed-sites between November 1, 1982, and February 28, 1983, on an hour-by-hour basis. From these data an additional variable was created--the hour-by-hour arithmetic mean of the values reported by the 15 sites. This synthethic data set is denoted by the three-digit code "AVG" in Table 6-12 and is referred to as the "composite" data set in the discussion that follows.

Table 6-13 summarizes the results of analyzing the hourly average values using BMDP program P2D.[4] Table 6-14 lists the date and time of the maximum value reported by each site. Ten of the 15 maximum values occurred during either the morning or the evening high traffic period (8:00, 17:00, or 18:00). Four of the 15 maximum values occurred on January 27, 1983. The maximum value in the composite data set was 15.8 ppm and occurred at 8:00 on December 17, 1982.

A supplementary file was created that contained daily maximum 1-hour and 8-hour values for all 16 data sets on a day-by-day basis. Daily maximum values were not determined for days with less than 18 hours out of the possible 24. Table 6-15 summarizes the results of analyzing the daily maximum 1-hour values using BMDP program P2D. Table 6-16 provides similar results for daily maximum 8-hour values. Table 6-17 lists the percentage of daily maximum 8-hour values at each site that exceed 7 ppm, 9 ppm, 12 ppm, and 15 ppm.

Only one site (Map Code A) reported daily maximum 1-hour values exceeding 35 ppm during the study period. However, 11 of the 15 fixed-site monitors reported daily maximum 8-hour values exceeding 9 ppm (Figure 6-3). These results suggest that fixed-site monitors operating in the Denver area are more likely to report violations of the current 8-hour National Ambient Air Quality Standard (NAAQS) than the current 1-hour NAAQS.

Two of the permanent monitors (Map Codes A and B) and three of the temporary monitors (Map Codes D, F, and J) reported daily maximum 8-hour values exceeding 15 ppm. These five monitors were all located in the central business district of Denver, an area of high traffic density. A detailed analysis of fixed-site data and associated meteorological conditions by the State of Colorado concluded that the critical meteorological conditions producing 8-hour CO concentrations in excess of 15 ppm were 1) wind speed < 6 mph, 2) morning temperature inversion $> 4^{o}C/100$ m, 3) inversion depth between 1000 and 1500 feet, and 4) high pressure with light winds at 700 mb and 500 mb levels.[1]

TABLE 6-13. SUMMARY STATISTICS FOR HOURLY AVERAGE CARBON MONOXIDE VALUES REPORTED BY DENVER MONITORING SITES BETWEEN NOVEMBER 1, 1982, AND FEBRUARY 28, 1983

Map code	SAROAD code	Number of hourly values	Hourly average carbon monoxide concentration, ppm								
							Percentiles				
			Minimum	Maximum	Mean	Std. dev.	10	25	50	75	90
A	060580002F01	2865	0.0	44.1	4.75	4.40	1.0	1.8	3.5	6.2	9.8
B	060580014F01	2621	0.0	26.5	3.38	3.75	0.4	0.9	2.0	4.5	8.4
C	060580013F01	2579	0.0	25.6	3.87	3.54	0.9	1.4	2.6	5.1	8.8
D	062080821F05	2693	0.0	26.7	2.97	3.06	0.5	1.0	2.0	3.8	6.6
E	062080822F05	2788	0.0	21.0	2.28	2.69	0.3	0.6	1.3	2.9	5.6
F	062080820F05	2777	0.0	29.4	2.94	3.07	0.5	1.0	1.9	3.8	6.9
G	062080823F05	2708	0.2	13.9	1.94	1.69	0.5	0.8	1.3	2.3	4.1
H	062080825F05	2744	0.0	14.0	1.53	1.54	0.2	0.5	1.0	2.0	3.5
I	062080818F05	2724	0.0	24.7	2.86	3.03	0.5	1.0	1.8	3.8	6.6
J	062080819F05	2618	0.0	26.8	2.94	3.13	0.5	1.0	2.0	3.9	6.6
K	060140002F01	2842	0.0	16.2	1.83	1.63	0.4	0.8	1.4	2.3	3.8
L	060120002F01	2846	0.0	23.8	3.04	2.85	0.7	1.1	2.1	4.0	6.6
M	060080002F01	2827	0.0	9.6	0.93	1.05	0.0	0.3	0.6	1.2	2.2
N	062080824F05	2724	0.0	24.7	2.86	3.04	0.5	0.9	1.8	3.8	14.6
O	062080817F05	2716	0.0	15.9	1.72	1.76	0.3	0.5	1.1	2.2	4.1
	Composite	2880	0.2	15.8	2.64	2.24	0.7	1.1	1.9	3.4	5.6

TABLE 6-14. DATE AND TIME OF MAXIMUM HOURLY AVERAGE CARBON MONOXIDE VALUE

Map code	SAROAD code	Maximum hourly avg., ppm	Date	Time
A	060580002F01	44.1	12-16-82	17:00
B	060580014F01	26.5	1-27-83	19:00
C	060580013F01	25.6	1-27-83	17:00
D	062080821F05	26.7	12-26-82	17:00
E	062080822F05	21.0	1-15-83	21:00
F	062080820F05	29.4	1-27-83	19:00
G	062080823F05	13.9	11-05-82	10:00
H	062080825F05	14.0	1-03-83	17:00
I	062080818F05	23.8	12-17-82	8:00
J	062080819F05	26.8	1-27-83	18:00
K	060140002F01	16.2	11-10-82	8:00
L	060120002F01	23.8	1-03-83	8:00
M	060080002F01	9.6	12-09-82	13:00
N	062080824F05	24.7	12-17-82	8:00
O	062080817F05	15.9	1-11-83	17:00

TABLE 6-15. SUMMARY STATISTICS FOR DAILY MAXIMUM 1-HOUR CARBON MONOXIDE VALUES REPORTED BY DENVER MONITORING SITES BETWEEN NOVEMBER 1, 1982, AND FEBRUARY 28, 1983

Map code	SAROAD code	Number of daily max. values	Daily maximum 1-hour carbon monoxide concentration, ppm								
			Minimum	Maximum	Mean	Std. dev.	Percentiles				
							10	25	50	75	90
A	060580002F01	120	1.5	44.1	12.87	7.41	5.6	8.0	10.5	16.6	23.7
B	060580014F01	108	0.6	26.5	10.33	5.58	2.8	5.9	9.9	14.2	17.3
C	060580013F01	108	2.0	25.6	11.22	5.26	4.4	7.4	10.6	14.3	19.1
D	062080821F05	113	1.0	26.7	8.89	5.11	3.6	5.6	7.9	10.7	16.8
E	062080822F05	120	0.5	21.0	7.92	4.60	2.6	4.7	7.1	10.5	14.1
F	062080820F05	118	0.8	29.4	8.71	4.75	3.2	5.6	8.0	11.1	15.0
G	062080823F05	115	0.8	13.9	5.30	2.71	2.3	3.3	4.8	7.0	9.5
H	062080825F05	118	0.7	14.0	4.53	2.47	2.0	2.5	4.0	6.2	7.9
I	062080818F05	114	0.8	23.8[a]	8.64	5.12	3.4	5.0	7.3	12.3	15.6
J	062080819F05	110	0.8	26.8	8.72	5.21	3.5	5.0	7.4	10.8	16.1
K	060140002F01	118	1.3	16.2	5.09	2.81	2.0	3.1	4.5	6.3	9.2
L	060120002F01	119	0.9	23.8	8.42	4.69	2.5	5.0	7.5	11.1	14.8
M	060080002F01	116	0.4	9.6	2.98	1.57	1.3	1.9	2.8	3.9	5.3
N	062080824F05	118	0.8	24.7	8.80	5.16	3.0	5.0	7.8	12.1	15.1
O	062080817F05	114	0.2	15.9	5.23	2.69	1.7	3.4	5.1	6.6	8.3
	Composite	120	0.7	15.8	6.62	3.16	2.8	4.5	6.0	8.3	10.6

[a] The maximum 1-hour value of 24.7 listed in Table 6-13 is not listed here because it occurred on a day which did not meet data completeness criteria discussed in Section 6.6.

TABLE 6-16. SUMMARY STATISTICS FOR DAILY MAXIMUM 8-HOUR CARBON MONOXIDE VALUES REPORTED BY DENVER MONITORING SITES BETWEEN NOVEMBER 1, 1982, AND FEBRUARY 28, 1983

Map code	SAROAD code	Number of daily max. values	Daily maximum 8-hour carbon monoxide concentration, ppm								
							Percentiles				
			Minimum	Maximum	Mean	Std. dev.	10	25	50	75	90
A	060580002F01	120	1.2	20.7	7.66	3.97	3.4	4.9	6.8	9.6	13.7
B	060580014F01	108	0.4	18.5	6.11	3.60	1.9	3.3	5.9	7.9	10.9
C	060580013F01	107	1.4	13.1	6.31	2.86	2.5	3.9	5.7	8.5	10.3
D	062080821F05	113	0.8	15.2	5.13	2.85	1.9	3.1	4.5	6.2	9.5
E	062080822F05	118	0.4	14.1	4.14	2.45	1.5	2.4	3.4	5.6	7.5
F	062080820F05	118	0.5	15.1	5.16	2.84	1.9	3.0	4.9	6.6	9.0
G	062080823F05	114	0.7	7.8	3.05	1.51	1.6	2.0	2.6	4.0	5.1
H	062080825F05	113	0.6	7.2	2.48	1.40	1.1	1.4	2.1	3.2	4.1
I	062080818F05	112	0.7	13.6	4.97	2.93	1.8	2.8	4.2	6.4	9.3
J	062080819F05	108	0.5	15.2	5.00	2.96	2.1	3.1	4.2	6.2	8.9
K	060140002F01	118	1.0	9.3	2.98	1.51	1.5	1.9	2.7	3.7	5.0
L	060120002F01	118	0.7	13.2	4.86	2.40	2.0	2.8	4.5	6.5	8.1
M	060080002F01	116	0.2	5.8	1.57	1.08	0.5	0.9	1.3	1.8	3.3
N	062080824F05	116	1.2	13.5	5.01	2.79	2.2	2.7	4.4	6.4	9.5
O	062080817F05	114	0.1	8.6	3.01	1.58	1.3	1.9	2.7	3.8	5.2
	Composite	120	0.6	10.3	4.16	2.01	1.7	2.9	3.7	5.3	7.0

TABLE 6-17. PERCENTAGE OF DAILY MAXIMUM 8-HOUR VALUES REPORTED BY DENVER MONITORING SITES EXCEEDING SELECTED CARBON MONOXIDE CONCENTRATIONS BETWEEN NOVEMBER 1, 1982, AND FEBRUARY 28, 1983

Map code	SAROAD code	Percentage of daily maximum 8-hour values			
		> 7 ppm	> 9 ppm	> 12 ppm	> 15 ppm
A	060580002F01	49.2	28.3	13.3	7.5
B	060580014F01	35.2	15.7	7.4	1.9
C	060580013F01	33.6	18.7	3.7	0
D	062080821F05	22.1	13.3	1.8	0.9
E	062080822F05	13.6	4.2	1.7	0
F	062080820F05	18.6	8.5	2.5	0.8
G	062080823F05	1.8	0	0	0
H	062080825F05	0.9	0	0	0
I	062080818F05	20.5	10.7	1.8	0
J	062080819F05	22.2	8.3	4.6	0.9
K	060140002F01	3.4	0.8	0	0
L	060120002F01	20.3	4.2	0.8	0
M	060080002F01	0	0	0	0
N	062080824F05	20.7	11.2	1.7	0
O	062080817F05	2.6	0	0	0

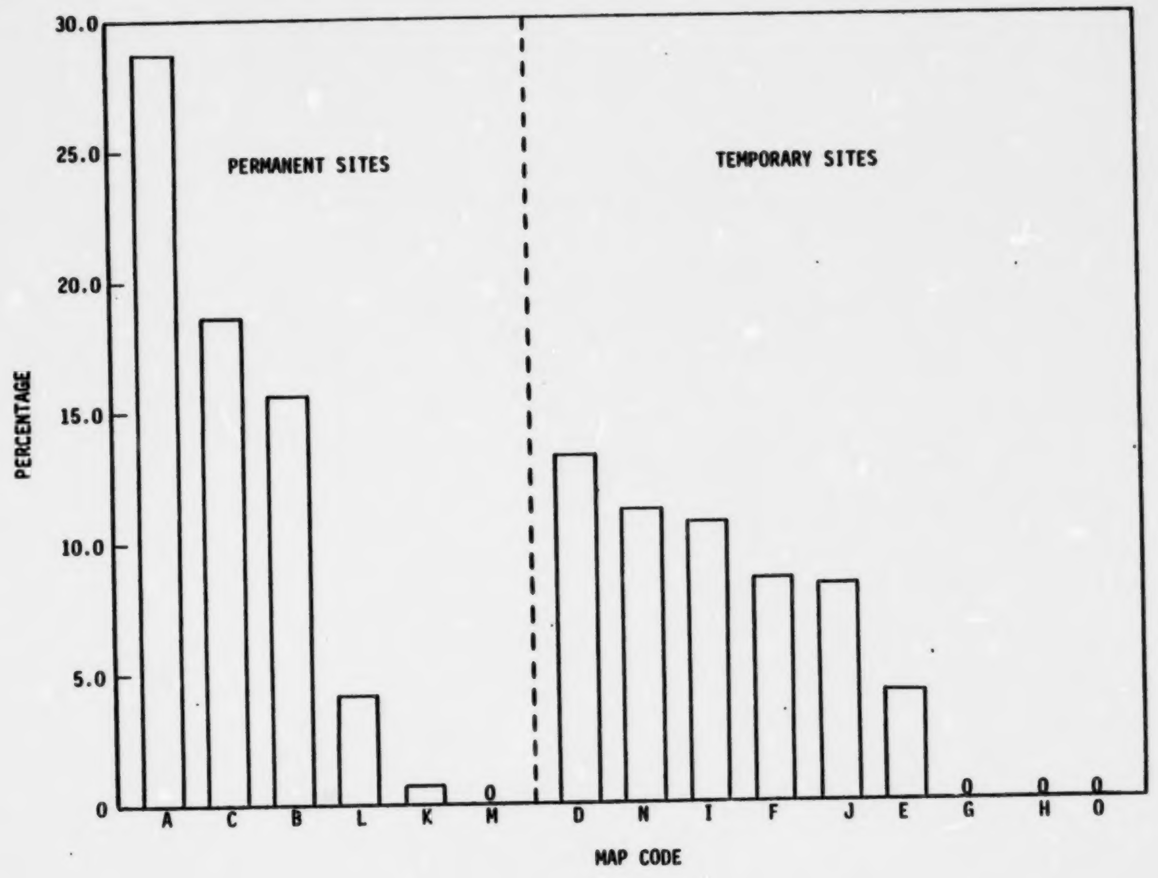


Figure 6-3. Percentage of daily maximum 8-h carbon monoxide values exceeding 9 ppm between November 1, 1982, and February 28, 1983, at fixed-site monitors.

6.6 FREQUENCY DISTRIBUTION OF DAILY MAXIMUM ONE-HOUR AND EIGHT-HOUR EXPOSURES

The Strategies and Air Standards Division of EPA is currently proposing that National Ambient Air Quality Standards (NAAQS's) for CO specify that the daily maximum 1-hour concentration shall not exceed 35 ppm more than once per year and that the daily maximum 8-hour concentration shall not exceed 9 ppm more than once per year. Compliance with these standards will probably be determined by fixed-site monitoring data. The Denver study, however, provides data useful in determining the distribution of daily maximum 1-hour and 8-hour exposures in the adult urban population of Denver, including the number of exposures exceeding 9 ppm and 35 ppm. Because the Denver study includes only the period November 1, 1982 to February 28, 1983, exposure estimates for an entire year cannot be made.

For each subject-day of valid PEM data, a determination was made of the maximum 1-hour average CO exposure beginning on a clock hour and the maximum 8-hour average CO exposure beginning on a clock hour. In determining these values, only 1-hour periods with at least 45 minutes of PEM data and 8-hour periods with at least six valid 1-hour values were considered. The 1-hour CO exposure for time t ($c_{1,t}$) is calculated by the expression

$$c_{1,t} = (1/\Sigma d_s)(\Sigma c_s d_s) \tag{6-8}$$

where c_s is a PEM value that starts and ends in the 1-hour period starting at hour t; d_s is the duration of the c_s value; and the summations include all PEM values that start and end in the 1-hour period starting at t. The 8-hour CO value for time t is the arithmetic mean of the six to eight valid 1-hour values calculated for the 8-hour period starting at time t. Maximum 1-hour and 8-hour exposures were not determined for subject-days containing less than 18 valid 1-hour values.

The daily maximum 1-hour and 8-hour exposures calculated for the study sample were extrapolated to the Denver target population using the weighting factors discussed in Section 2.4. Figures 6-4 and 6-5 present histograms of these results. Note that frequencies are given in person-days and that frequencies are not indicated for concentrations exceeding 60 ppm. Tables 6-18 and 6-19 present weighted and unweighted summary statistics. The weighted means for daily maximum 1-hour and 8-hour exposures during the study period are 10.0 ppm and 4.9 ppm, respectively. Approximately 3.0 percent of the

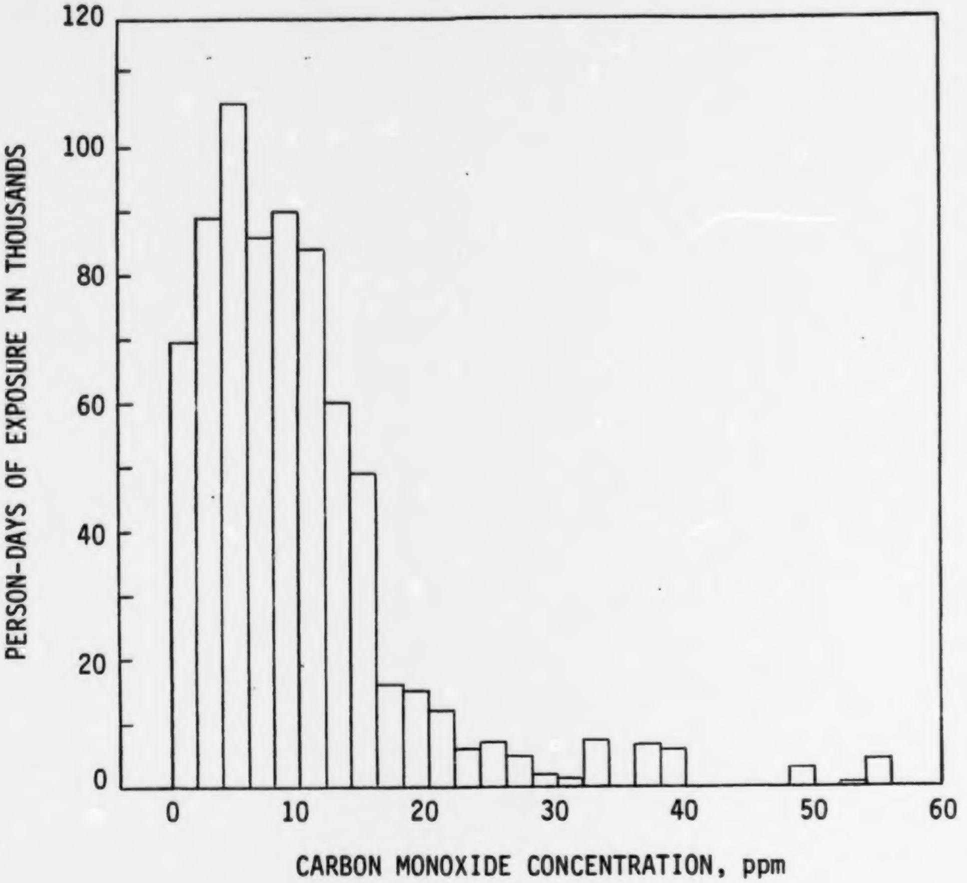


Figure 6-4. Histogram of estimated maximum 1-hour exposures to carbon monoxide in the Denver target population.

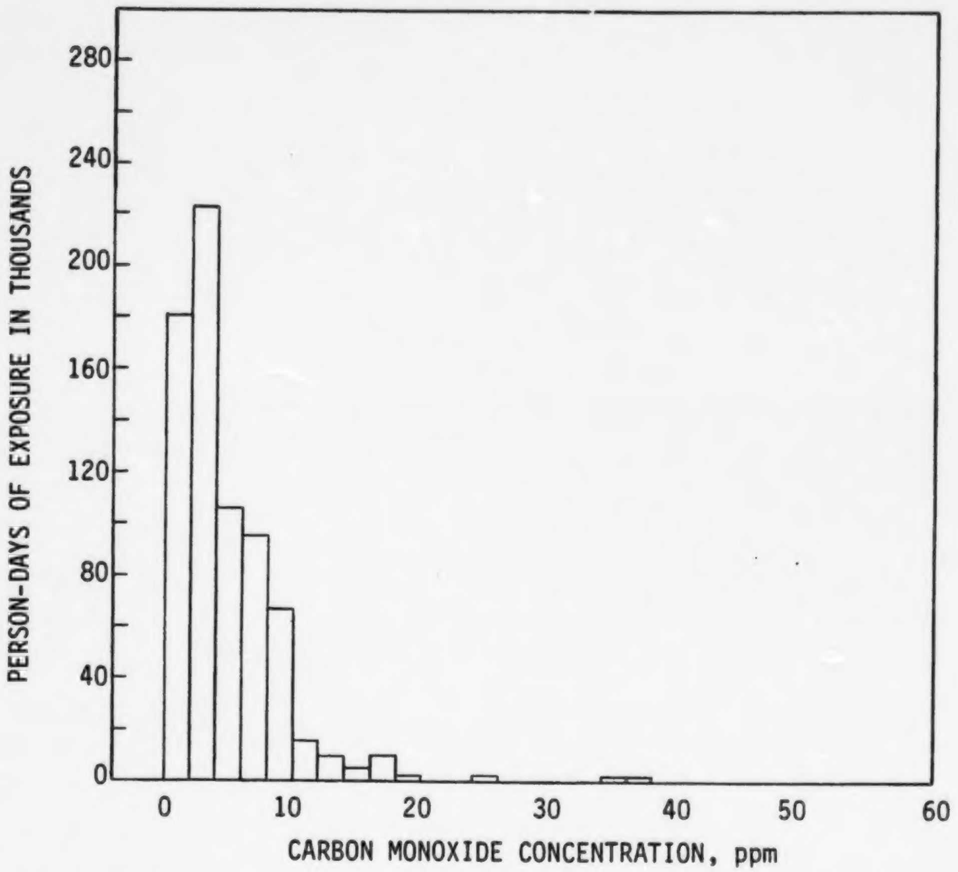


Figure 6-5. Histogram of estimated maximum 8-hour exposures to carbon monoxide in the Denver target population.

TABLE 6-18. SUMMARY STATISTICS FOR DAILY MAXIMUM 1-HOUR CARBON MONOXIDE EXPOSURES (WEIGHTED AND UNWEIGHTED)

Statistic	Value	
	Weighted	Unweighted
Minimum, ppm	0.0	0.0
Maximum, ppm	91.2	91.2
Mean, ppm	10.0	10.4
10th percentile, ppm	2.2	2.6
25th percentile, ppm	4.1	4.8
50th percentile, ppm	8.0	8.4
75th percentile, ppm	12.7	12.6
90th percentile, ppm	18.5	19.9
95th percentile, ppm	26.3	26.3
99th percentile, ppm	47.0	48.0
Percentage exceeding 35 ppm	3.0	2.6

TABLE 6-19. SUMMARY STATISTICS FOR DAILY MAXIMUM 8-HOUR CARBON MONOXIDE EXPOSURES (WEIGHTED AND UNWEIGHTED)

Statistic	Value	
	Weighted	Unweighted
Minimum, ppm	0.0	0.0
Maximum, ppm	44.0	44.0
Mean, ppm	4.9	5.0
10th percentile, ppm	1.1	0.9
25th percentile, ppm	2.0	2.2
50th percentile, ppm	3.5	3.8
75th percentile, ppm	6.9	6.6
90th percentile, ppm	9.4	9.7
95th percentile, ppm	12.1	12.8
99th percentile, ppm	25.6	25.0
Percentage exceeding 9 ppm	10.7	12.7

daily maximum 1-hour exposures exceed 35 ppm; approximately 10.7 percent of the daily maximum 8-hour exposures exceed 9 ppm.

The estimates presented in Figures 6-4 and 6-5 and in Tables 6-18 and 6-19 should not be interpreted as representing the exposure profile of the target population over the entire study period. They can be more properly interpreted as representing the exposure profile of the target population over a two-day period that is a population-weighted average of all the two-day sampling periods of the study. Because no adjustments were made to the estimates for day-to-day variations in sample size, days with larger sample sizes generally receive greater representation in the exposure profile.

Linear regression analyses were performed to relate daily maximum 1-hour exposures ($c_{1,\ max}$) to daily maximum 8-hour exposures ($c_{8,\ max}$). Omitting one outlier and using the daily maximum 8-hour value as the independent variable, weighted linear regression of 801 person-days of data yields the relationship

$$\hat{c}_{1,\ max} = 2.57 + (1.53)(c_{8,max}), \tag{6-9}$$

with $R^2 = 0.69$. Omitting the same outlier and using the daily maximum 1-hour value as the independent variable yields the relationship

$$\hat{c}_{8,max} = 0.36 + (0.45)(c_{1,max}); \tag{6-10}$$

again $R^2 = 0.69$. Equation 6-9 predicts that a member of the Denver target population who receives a daily maximum 8-hour exposure of 9 ppm would receive a daily maximum 1-hour exposure of 16.3 ppm. Similarly, Equation 6-10 predicts a person receiving a daily maximum 1-hour exposure of 35 ppm would receive a daily maximum 8-hour exposure of 16.1 ppm.

6.7 VARIATION IN EXPOSURE WITH MICROENVIRONMENT

One of the principal reasons for collecting activity diary data is to provide a means for relating exposure to a subject's microenvironment, i.e., the subject's immediate physical surroundings. The activity diary codes discussed in Section 3.6 can be combined in a variety of ways to designate microenvironments of interest. The initial analyses discussed here considered the four-digit code created by combining the two-digit B (location) code with the two-digit D3 (transit mode) code. Examples of microenvironment codes occurring in the SAMPLE-DATA file include 0193 (in transit - motorcycle), 52bb (indoors - public garage), and 09bb (uncertain).

Valid individual PEM values with durations of 60 minutes or less were used to calculate the weighted mean and standard deviation of PEM values grouped by microenvironment. Table 6-20 lists these results for each microenvironment code occurring in the SAMPLE-DATA file, excluding a few illegal B/D3 combinations that appear to have resulted from coding errors. The microenvironments are listed in descending order by mean CO concentration. The results suggest that microenvironments associated with motor vehicles had the highest CO levels in Denver during the study period.

Table 6-21 lists the weighted mean of the occupancy periods for each microenvironment except indoors - residence (Code 02bb). An occupancy period begins when a subject enters a new microenvironment and ends when the subject leaves the microenvironment. Mean occupancy periods for the indoor residential microenvironment could not be determined accurately from activity diary data because subjects were usually occupying residences before the first diary entry and after the last diary entry.

Mean occupancy periods range from 431.9 minutes (indoors - manufacturing facility) to 7.4 minutes (outdoors - residential garage or carport). Mean occupancy periods for in-transit microenvironments associated with motor vehicles and high CO levels are 30.8 minutes for trucks, 28.0 minutes for buses, 25.9 minutes for cars, and 23.0 minutes for motorcycles. The value for indoors - public garage (29.4 minutes) is higher than expected and may be the result of errors in recording activity diary information.

6.8 CONTRIBUTIONS OF ATTACHED GARAGES, GAS STOVES, AND SMOKING TO INDOOR RESIDENTIAL EXPOSURES

The activity diary (Appendix E) solicits information concerning the presence of attached garages (Item E1), of operating gas stoves (Item E2), and of smokers (Item F). An analysis was conducted to determine the contribution of each of these potential CO sources to indoor residential exposure.

TABLE 6-20. MICROENVIRONMENTS LISTED IN DESCENDING ORDER OF WEIGHTED MEAN CO CONCENTRATION

Code		Microenvironment			CO concentration, ppm	
B	D3	Category	Subcategory	n	Mean	Std. dev.
52	a	Indoors	Public garage	116	13.46	18.14
01	93	In transit	Motorcycle	22	9.79	8.15
54	bb	Indoors	Service station or motor vehicle repair facility	125	9.17	9.33
01	03	In transit	Bus	76	8.52	7.08
72	a	Outdoors	Public garage	29	8.20	5.33
01	02	In transit	Car	3632	8.10	9.88
71	bb	Outdoors	Residential garage or carport	22	7.53	8.93
62	bb	Indoors	Other location	427	7.40	17.97
01	04	In transit	Truck	405	7.03	9.89
55	bb	Indoors	Other repair shop	55	5.64	7.67
58	bb	Indoors	Shopping mall	58	4.90	6.50
51	bb	Indoors	Residential garage	66	4.35	7.06
07	c	Outdoors	Within 10 yards of road	496	4.05	5.44
01	01	In transit	Walking	619	3.88	6.61
bb	bb	Not specified	Not specified	586	3.79	6.57
05	bb	Indoors	Restaurant	524	3.71	4.35
74	bb	Outdoors	Service station or motor vehicle repair facility	12	3.68	3.84
03	c	Indoors	Office	2287	3.59	4.18
73	d	Outdoors	Parking lot	61	3.45	4.23
56	bb	Indoors	Auditorium, sports arena, concert hall, etc.	100	3.37	4.76
04	bb	Indoors	Store	734	3.23	5.56
80	bb	Outdoors	Other location	126	3.17	5.47
59	bb	Indoors	Health care facility	351	2.22	4.25
61	bb	Indoors	Other public building	115	2.15	3.26
53	bb	Indoors	Manufacturing facility	42	2.04	2.55
02	bb	Indoors	Residence	21543	2.04	4.06
77	bb	Outdoors	School grounds	16	1.99	3.39
60	bb	Indoors	School	426	1.64	2.76
57	bb	Indoors	Church	179	1.56	3.35
76	bb	Outdoors	Residential grounds	74	1.36	2.24
01	92	In transit	Bicycle	9	1.34	3.61
78	bb	Outdoors	Sports arena, amphitheater, etc.	29	0.97	2.80
79	bb	Outdoors	Park or golf course	21	0.69	1.01

[a] Includes D3 = bb, 01, and 02.

[b] Blank.

[c] Includes D3 = bb and 01.

[d] Includes D3 = bb, 01, 02, and 03.

TABLE 6-21. MICROENVIRONMENTS LISTED IN DESCENDING ORDER OF WEIGHTED MEAN OCCUPANCY PERIOD

Code		Microenvironment[a]			Occupancy period, minutes	
B	D3	Category	Subcategory	n	Mean	Std. dev.
53	bb	Indoors	Manufacturing facility	8	431.9	199.8
03	c	Indoors	Office	610	206.9	167.3
55	bb	Indoors	Other repair shop	11	192.4	121.3
78	bb	Outdoors	Sports arena, amphitheater, etc.	6	191.6	111.0
60	bb	Indoors	School	100	165.0	159.8
59	bb	Indoors	Health care facility	91	162.4	142.5
57	bb	Indoors	Church	57	115.7	57.3
56	bb	Indoors	Auditorium, sports arena, concert hall, etc.	38	112.0	77.0
80	bb	Outdoors	Other location	60	93.1	182.8
62	bb	Indoors	Other location	188	91.1	103.9
05	bb	Indoors	Restaurant	267	79.1	109.2
61	bb	Indoors	Other public building	52	77.8	60.8
58	bb	Indoors	Shopping mall	24	77.3	65.0
54	bb	Indoors	Service station or motor vehicle repair facility	53	72.3	87.1
79	bb	Outdoors	Park or golf course	11	60.4	84.3
04	bb	Indoors	Store	400	48.4	73.2
bb	bb	Not specified	Not specified	320	37.3	57.1
07	c	Outdoors	Within 10 yards of road	379	31.2	56.6
01	04	In transit	Truck	300	30.8	43.4
76	bb	Outdoors	Residential grounds	49	30.8	36.2
52	d	Indoors	Public garage	77	29.4	77.1
01	03	In transit	Bus	68	28.0	24.3
01	02	In transit	Car	2593	25.9	46.1
01	93	In transit	Motorcycle	17	23.0	9.9
51	bb	Indoors	Residential garage	49	23.0	39.5
01	01	In transit	Walking	511	20.0	46.9
73	e	Outdoors	Parking lot	67	16.4	37.8
01	92	In transit	Bicycle	13	16.1	10.2
77	bb	Outdoors	School grounds	15	12.8	6.8
72	d	Outdoors	Public garage	26	10.7	26.0
74	bb	Outdoors	Service station or motor vehicle repair service	12	7.5	2.4
71	bb	Outdoors	Residential garage or carport	20	7.4	17.5

[a] Omits indoor residential microenvironment (Code 02bb).

[b] Blank.

[c] Includes D3 = bb and 01.

[d] Includes D3 = bb, 01, and 02.

[e] Includes D3 = bb, 01, 02, and 03.

Table 6-22 presents the weighted means of residential exposures grouped according to the presence or absence of each factor. The differences presented in the table were calculated by subtracting the weighted means without sources from the weighted means with sources. A positive difference suggests that the indicated source made a positive contribution to residential exposure. All three sources yielded positive differences. Gas stove operation produced the largest difference (2.59 ppm), followed by smokers (1.59 ppm) and attached garages (0.41 ppm). The student t test was performed on the logarithms of the PEM values because this transformation yielded distributions that more closely approached normality. As indicated in Table 6-22, all three sources produced shifts in the mean CO concentration that were significant at the $p = 0.0005$ level.

6.9 LINEAR RELATIONSHIPS BETWEEN FIXED AND PERSONAL MONITOR VALUES

In the absence of personal monitoring data, estimates of population exposure are often based on fixed-site monitoring data. In some applications of the NAAQS Exposure Model (NEM),[5] for example, the air quality in a particular microenvironment is estimated using the equation

$$x_{m,t} = a_m + \left(b_m\right)\left(x_{mon,t}\right) \tag{6-11}$$

where $x_{m,t}$ is the estimated pollutant concentration in microenvironment m at time t; a_m is an additive factor related to pollutant sources in the microenvironment (e.g., gas stoves in the residential microenvironment); b_m is a multiplicative factor; and $x_{mon,t}$ is the air pollutant concentration reported by a particular fixed-site monitor at time t. Equation 6-11 implies that a strong, linear relationship exists between pollutant levels in certain microenvironments and simultaneous pollutant levels measured at fixed-site monitors. This assumption can be examined in the case of CO by performing linear regression analyses that use PEM values grouped by microenvironment as the dependent variable and simultaneously-recorded fixed-site values as the independent variable.

To perform these analyses, each PEM value must be paired with a value reported by a single fixed-site monitor. Since the census tract of each non-transit PEM value is known, it seems reasonable to assign a single fixed-site

TABLE 6-22. WEIGHTED MEANS OF RESIDENTIAL EXPOSURES GROUPED ACCORDING TO THE PRESENCE OR ABSENCE OF SELECTED INDOOR CARBON MONOXIDE SOURCES

	Carbon monoxide concentration, ppm					
	Source present		Source absent			
CO source	Mean	Std. dev.	Mean	Std. dev.	Difference in means	Significance level of t statistic[a]
Attached garage	2.29	5.34	1.88	3.00	0.41	$p < 0.0005$
Operating gas stove	4.52	6.10	1.93	3.92	2.59	$p < 0.0005$
Smokers	3.48	6.58	1.89	3.69	1.59	$p < 0.0005$

[a] Student t test was performed on logarithms of PEM values.

monitor to each census tract in the study area. Whenever a PEM value is reported for a given census tract, it is paired with the simultaneous value of the fixed-site monitor assigned to that census tract.

One possible method of assigning fixed-site monitors to census tracts is to use the monitor located nearest to the geographic centroid of the census tract. An implicit assumption of this method is that the correlation between ambient CO measurements taken at two locations increases as the separation distance decreases. As a test of this assumption, the correlations between all pairs of fixed-site monitors (including the "composite monitor") were calculated using BMDP program P8D. Figure 6-6 presents output from program P8D listing pairwise frequencies with both variables present. All frequencies exceed 2321 out of a possible 2880. Figure 6-7 is the correlation matrix. Table 6-23 lists the correlations (excluding those involving the composite site) from largest to smallest, the associated pair of fixed-site monitors, and the distance between the monitors. Correlations vary from 0.1016 to 0.8897; the median correlation is 0.6499.

A cursory review of the Table 6-23 suggests that correlation (C) decreases as separation distance (D) increases. As a test for such a relationship, the Spearman and Kendall rank correlation tests were performed using -C and D. The Spearman r_s value was 0.803; the Kendall τ value was 0.616. Both are significant at the $p = 0.0001$ confidence level, indicating a strong likelihood

```
PAIRWISE FREQUENCIES WITH BOTH VARIABLES PRESENT
------------------------------------------------

             HIG      ARV      AUR      DU2      D13      D14      817      818      819      820
               1        2        3        4        5        6        7        8        9       10
HIG   1     2827
ARV   2     2795     2885
AUR   3     2791     2810     2842
DU2   4     2814     2833     2829     2865
D13   5     2529     2547     2555     2569     2579
D14   6     2569     2588     2584     2609     2322     2621
817   7     2669     2685     2631     2703     2434     2501     2716
818   8     2673     2651     2649     2670     2415     2459     2555     2683
819   9     2578     2589     2594     2608     2359     2383     2488     2463     2618
820  10     2729     2747     2741     2763     2496     2529     2622     2600     2597     2777
821  11     2651     2662     2658     2680     2416     2448     2557     2527     2473     2619
822  12     2739     2756     2753     2775     2499     2540     2636     2618     2549     2698
823  13     2659     2675     2683     2694     2495     2462     2568     2536     2465     2611
824  14     2676     2693     2673     2713     2449     2480     2583     2581     2509     2662
825  15     2695     2715     2709     2730     2461     2514     2594     2586     2496     2653
AVG  16     2827     2846     2842     2865     2579     2621     2716     2683     2618     2777

             821      822      823      824      825      AVG
              11       12       13       14       15       16
821  11     2693
822  12     2621     2788
823  13     2531     2630     2738
824  14     2560     2649     2560     2724
825  15     2565     2687     2593     2601     2744
AVG  16     2693     2788     2718     2724     2744     2880
```

Figure 6-6. Pairwise frequency table for 15 Denver fixed-site monitors and composite data set (labeled AVG).

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CORPAIR  CORRELATION MATRIX
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                  HIG       ARV       AUR       002       013       014       A17       A18       A19       A20
                    1         2         3         4         5         6         7         8         9        10

HIG       1    1.0000
ARV       2     .1618    1.0000
AUR       3     .3976     .4412    1.0000
002       4     .2681     .5756     .6180    1.0000
013       5     .2114     .6405     .6830     .7276    1.0000
014       6     .1669     .7092     .4624     .6617     .7029    1.0000
A17       7     .1701     .5695     .6241     .6587     .7690     .6956    1.0000
A18       8     .1559     .6042     .5724     .7780     .8075     .8000     .7809    1.0000
A19       9     .1718     .6194     .5413     .8324     .7705     .7998     .6931     .8713    1.0000
A20      10     .1764     .6844     .5653     .8052     .7633     .8897     .7569     .8791     .8827    1.0000
A21      11     .2535     .6039     .6414     .7989     .8525     .6943     .7077     .8419     .8692     .7878
A22      12     .3683     .6084     .7010     .7047     .7248     .6899     .6257     .7056     .7170     .7443
A23      13     .5475     .4034     .6849     .5445     .5706     .4319     .5265     .4876     .5049     .5180
A24      14     .3683     .5105     .6432     .6931     .7287     .5851     .5924     .6728     .7192     .6587
A25      15     .6157     .4386     .7291     .6069     .6105     .4463     .5536     .4939     .5160     .5306
AVG      16     .3248     .7302     .7352     .8761     .8856     .8381     .8072     .8979     .9079     .9140

                  A21       A22       A23       A24       A25       AVG
                   11        12        13        14        15        16

A21      11    1.0000
A22      12     .7665    1.0000
A23      13     .5918     .6709    1.0000
A24      14     .8223     .7671     .6409    1.0000
A25      15     .6012     .6964     .8933     .6607    1.0000
AVG      16     .9176     .8637     .6871     .8326     .7170    1.0000

NUMBER OF INTEGER WORDS OF STORAGE USED IN PRECEDING    PROBLEM    1824
CPU TIME USED      35.890 SECONDS
```

Figure 6-7. Correlation matrix for 15 Denver fixed-site monitors and composite data set (labeled AVG).

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TABLE 6-23. CORRELATIONS AND DISTANCES BETWEEN PAIRS OF FIXED SITES LISTED IN ORDER OF CORRELATION

Rank	Correlation	Three-digit code		Separation distance, miles
		Monitor A	Monitor B	
1	0.8897	820	014	1.95
2	0.8827	820	819	1.85
3	0.8791	820	818	2.13
4	0.8713	819	818	2.48
5	0.8692	821	819	1.85
6	0.8525	821	013	2.65
7	0.8419	821	818	3.38
8	0.8324	819	002	0.94
9	0.8223	824	821	4.64
10	0.8083	825	823	3.24
11	0.8075	818	013	2.37
12	0.8052	820	002	1.64
13	0.8000	818	014	3.70
14	0.7998	819	014	1.67
15	0.7989	821	002	2.13
16	0.7878	821	820	3.59
17	0.7804	818	817	6.38
18	0.7780	818	002	1.53
19	0.7705	819	013	3.21
20	0.7690	817	013	5.79
21	0.7671	824	822	3.77
22	0.7665	822	821	4.47
23	0.7633	820	013	4.08
24	0.7569	820	817	8.48
25	0.7443	822	820	6.35
26	0.7291	825	AUR	8.09
27	0.7287	824	013	6.59
28	0.7276	013	002	2.55
29	0.7248	822	013	7.12
30	0.7192	824	819	6.21
31	0.7170	822	819	4.99
32	0.7092	014	ARV	5.13
33	0.7077	821	817	8.44
34	0.7056	822	818	7.36
35	0.7047	822	002	5.86
36	0.7029	014	013	4.88
37	0.7010	822	AUR	11.20
38	0.6964	825	822	9.38
39	0.6956	817	014	10.01
40	0.6943	821	014	3.24

(continued)

TABLE 6-23 (continued)

Rank	Correlation	Three-digit code		Separation distance, miles
		Monitor A	Monitor B	
41	0.6931	824	002	6.77
42	0.6931	819	817	8.55
43	0.6899	822	014	4.64
44	0.6849	823	AUR	6.17
45	0.6844	820	ARV	5.41
46	0.6800	013	AUR	5.23
47	0.6728	824	818	7.99
48	0.6709	823	822	7.01
49	0.6617	014	002	2.41
50	0.6607	825	824	5.62
51	0.6587	817	002	7.64
52	0.6587	824	820	7.95
53	0.6499	824	823	3.52
54	0.6414	821	AUR	7.29
55	0.6405	013	ARV	9.42
56	0.6404	824	AUR	8.97
57	0.6257	822	817	12.91
58	0.6241	817	AUR	4.74
59	0.6194	819	ARV	6.59
60	0.6180	002	AUR	7.78
61	0.6157	825	HIG	4.26
62	0.6105	825	013	9.17
63	0.6084	822	ARV	8.55
64	0.6042	818	ARV	7.40
65	0.6039	821	ARV	8.30
66	0.6012	825	821	8.69
67	0.6009	825	002	10.71
68	0.5924	824	817	11.97
69	0.5918	823	821	5.51
70	0.5851	824	014	6.84
71	0.5750	002	ARV	6.94
72	0.5724	818	AUR	7.29
73	0.5706	823	013	6.00
74	0.5695	817	ARV	13.29
75	0.5653	820	AUR	9.24
76	0.5536	825	817	12.56
77	0.5475	823	HIG	6.21
78	0.5445	823	002	7.47
79	0.5413	819	AUR	8.41
80	0.5306	825	820	12.24
81	0.5265	823	817	10.08

(continued)

TABLE 6-23 (continued)

Rank	Correlation	Three-digit code		Separation distance, miles
		Monitor A	Monitor B	
82	0.5180	823	817	10.08
83	0.5160	825	819	10.53
84	0.5105	824	ARV	11.69
85	0.5049	823	819	7.36
86	0.4939	825	818	11.37
87	0.4876	823	818	8.16
88	0.4624	014	AUR	10.08
89	0.4463	825	014	11.69
90	0.4412	AUR	ARV	14.62
91	0.4386	825	ARV	16.81
92	0.4318	823	014	8.58
93	0.4033	823	ARV	13.74
94	0.3976	AUR	HIG	12.10
95	0.3680	824	HIG	6.17
96	0.3640	822	HIG	9.35
97	0.2681	002	HIG	12.80
98	0.2535	821	HIG	10.64
99	0.2114	013	HIG	12.00
100	0.1764	820	HIG	14.13
101	0.1718	819	HIG	12.31
102	0.1701	817	HIG	16.29
103	0.1559	818	HIG	13.88
104	0.1069	014	HIG	13.05
105	0.1018	ARV	HIG	17.72

that the two quantities are not independent. Stepwise linear regression was then used to fit the model

$$\hat{C} = a + b_1D^3 + b_2D^2 + b_3D + b_4D^{-1} + b_5D^{-2} + b_6D^{-3} \qquad (6\text{-}12)$$

to the data in Table 6-23. The analysis indicated that all terms except a and b_3D could be discarded as not significantly improving the fit. The resulting simplified model

$$\hat{C} = 0.901 - (0.038)(D) \qquad (6\text{-}13)$$

yields an R^2 value of 0.645. The residual sum of squares (RSS) between C and $\hat{C}$ is 1.193. Additional linear regressions were performed using the transformed variables listed in Table 6-24. The results suggested that the model

TABLE 6-24. RESULTS OF LINEAR REGRESSION ANALYSES USING SELECTED TRANSFORMATIONS OF CORRELATION (C) AND DISTANCE BETWEEN SITES (D)

Variables		Linear regression		
Dependent	Independent	Intercept	Slope	R^2
C^2	D	0.723	-0.042	0.671
$C^{1.5}$	D	0.811	-0.042	0.666
$C^{2.5}$	D	0.642	-0.040	0.665
C^3	D	0.570	-0.038	0.652
ln C	ln D	0.261	-0.440	0.396
1/C	D	0.216	0.235	0.379
$1/C^2$	D	-7.710	1.832	0.252
$1/C^3$	D	-72.720	14.147	0.179

$$\hat{C}^2 = 0.723 - (0.042)(D) \qquad (6\text{-}14)$$

also provides a good fit ($R^2 = 0.671$) to the data. In this case, the RSS between C and $\hat{C}$ is 1.247. Both models predict an increase in correlation as distance between monitoring locations decreases.

This analysis suggested that a linear regression analysis that pairs each nontransit PEM value with the simultaneous value reported at the nearest fixed site might be appropriate for the Denver study data. A computer program was written that determined the fixed-site monitor nearest to each census tract centroid. Weighted linear regression analyses were then performed with the data grouped by selected microenvironment codes (i.e., B + D3). Results for nontransit microenvironments for which $n \geq 10$ are listed in Table 6-25 in order of R^2 value. Values of R^2 range from 0.46 to 0.00. As might be expected, many of the microenvironments with small R^2 values are associated with local CO sources that tend to reduce the correlation between PEM value and nearest fixed-site value; however, other microenvironments associated with local CO sources have relatively large R^2 values.

TABLE 6-25. RESULTS OF WEIGHTED LINEAR REGRESSION ANALYSES WITH NONTRANSIT PEM VALUE AS DEPENDENT VARIABLE AND SIMULTANEOUS VALUE AT NEAREST FIXED SITE AS INDEPENDENT VARIABLE

Code		Microenvironment[a]		Linear regression				
B	D3	Category	Subcategory	n	Intercept	Slope	R^2	p
80	bb	Outdoors	Other location	115	0.35	1.11	0.46	0.000
79	bb	Outdoors	Park or golf course	18	-0.09	0.39	0.44	0.003
77	bb	Outdoors	School grounds	15	-0.37	1.15	0.27	0.049
54	bb	Indoors	Service station or motor vehicle repair facility	112	4.18	1.63	0.27	0.000
05	bb	Indoors	Restaurant	486	1.69	0.76	0.25	0.000
74	bb	Outdoors	Service station or motor vehicle repair facility	11	1.61	1.21	0.23	0.134
07	c	Outdoors	Within 10 yards of road	468	1.58	0.89	0.21	0.000
57	bb	Indoors	Church	178	0.09	0.70	0.21	0.000
73	d	Outdoors	Parking lot	51	2.26	0.60	0.21	0.001
55	bb	Indoors	Other repair shop	46	3.69	0.88	0.18	0.003
78	bb	Outdoors	Sports arena, amphitheater, etc.	16	3.05	-1.76	0.15	0.128
61	bb	Indoors	Other public building	111	0.74	0.42	0.14	0.000
58	bb	Indoors	Shopping mall	55	1.24	1.43	0.14	0.005
04	bb	Indoors	Store	675	1.67	0.56	0.09	0.000
59	bb	Indoors	Health care facility	336	0.97	0.45	0.09	0.000
02	bb	Indoors	Residence	20969	1.00	0.43	0.07	0.000
60	bb	Indoors	School	342	0.97	0.32	0.07	0.000
03	bb	Indoors	Office	2090	2.53	0.34	0.05	0.000
71	bb	Outdoors	Residential garage or carport	22	5.67	0.61	0.05	0.304
bb	bb	Not specified	Not specified	583	2.07	0.63	0.05	0.000
76	bb	Outdoors	Residential grounds	70	0.84	0.30	0.04	0.099
e		-	Public garage	139	8.44	0.72	0.04	0.019
56	bb	Indoors	Auditorium, sports arena, concert hall, etc.	94	2.25	0.38	0.04	0.060
53	bb	Indoors	Manufacturing facility	41	1.41	0.18	0.03	0.246
51	bb	Indoors	Residential garage	66	3.98	0.14	0.00	0.662
62	bb	Indoors	Other location	381	7.94	0.07	0.00	0.791

[a] Listed in order of R^2 value.

[b] Blank.

[c] Includes D3 = bb and 01.

[d] Includes D3 = bb, 01, 02, and 03.

[e] Includes codes 52bb, 5201, 5202, 72bb, 7201, and 7202.

[p] Probability that slope = 0.

An untried method of assigning fixed-site monitors to census tracts is to determine the traffic density of each census tract and then select a fixed-site monitor located in a census tract with similar traffic density. The quantities TDEN and RDEN discussed in Section 5 would facilitate this method. Such an approach may yield higher correlations between the nontransit PEM values and the fixed site values than those listed in Table 6-25.

Table 6-25 does not list any in-transit microenvironments because of the difficulty in pairing in-transit PEM values with a "nearest" fixed-site monitor value. In the SAMPLE-DATA file, each in-transit PEM value has two census tract listings, one associated with the start address and the other with the end address. Neither may be a good indicator of the CO conditions encountered during the trip. One alternative procedure is to pair the in-transit PEM values with simultaneous values from the composite data set described in Section 6.5. As indicated in Figure 6-7, the composite data set shows relatively high correlations with most of the fixed-site data sets. It also provides an indication of the average CO level in the study area. Table 6-26 lists the results of linear regression analyses pairing in-transit PEM values with simultaneous values from the composite data set. Values of R^2 range from 0.58 (motorcycle) to 0.04 (car).

TABLE 6-26. RESULTS OF WEIGHTED LINEAR REGRESSION ANALYSES WITH IN-TRANSIT PEM VALUE AS DEPENDENT VARIABLE AND SIMULTANEOUS VALUE FROM COMPOSITE DATA SET AS INDEPENDENT VARIABLE

Code		In-transit subcategory	Linear regression				
B	D3		n	Intercept	Slope	R^2	p
01	93	Motorcycle	22	4.50	2.14	0.58	0.000
01	03	Bus	76	3.17	2.02	0.36	0.010
01	01	Walking	619	0.06	1.47	0.23	0.000
01	04	Truck	405	3.27	1.54	0.11	0.000
01	02	Car	3632	6.01	0.78	0.04	0.000
01	a	All	4763	5.15	0.92	0.05	0.000

[a] Includes D3 codes 01, 02, 03, 04, 92, and 93.

[p] Probability that slope = 0.

An untried alternative is to pair all in-transit PEM values with simultaneous values at a single traffic-oriented monitor. Such an analysis might yield higher correlations between the in-transit PEM values and the fixed-site values than those reported in Table 6-26.

6.10 DAY-OF-THE-WEEK VARIATIONS IN THE DIURNAL PATTERNS OF PERSONAL EXPOSURES AND FIXED-SITE VALUES

Each subject-day of valid PEM data was converted into 1-hour CO exposures using Equation 6-8. Weighted means of these 1-hour exposures were calculated by clock hour to determine the diurnal patterns for weekdays, Saturdays, and Sundays presented in Figures 6-8, 6-9, and 6-10. For comparison purposes, the corresponding diurnal patterns for the composite fixed site are also presented.

On weekdays, exposure decreases from midnight until 6:00 and then shows a dramatic increase during the 7:00 rush hour. Exposure remains above 2.7 ppm until 20:00. A slight decrease occurs in mid-morning followed by a noon-hour rise and a mid-afternoon decrease. Exposure increases again during the evening rush hours, and then decreases during the later evening hours. The diurnal pattern for the composite site shows a pronounced peak between 7:00 and 10:00 and a somewhat lower peak starting at 17:00. Unlike the exposure pattern, the fixed-site pattern shows a large dip in the middle of the day.

Saturday exposure also shows a dramatic increase at 7:00. However, the overall exposure patterns for weekdays and Saturday are quite different. Saturday exposure peaks at 20:00; weekday exposure peaks at 16:00. The Saturday diurnal pattern for the composite site is quite similar to the Saturday pattern for exposure in the period between 16:00 and 24:00. However, the midday peak observed in the exposure pattern does not occur in the composite-site pattern.

Sunday exposure is highest at midnight, a pattern consistent with the high Saturday night exposures. Exposure shows a slight mid-morning peak followed by a noon-hour jump. Exposure falls off during the afternoon and then increases at 17:00. The Sunday night exposure pattern is similar in shape to that of Saturday night, although the corresponding hourly exposure means are much lower on Sunday night. The Sunday diurnal pattern for the composite site is similar to the Sunday exposure pattern. Again, the main difference between the two patterns occurs at midday.

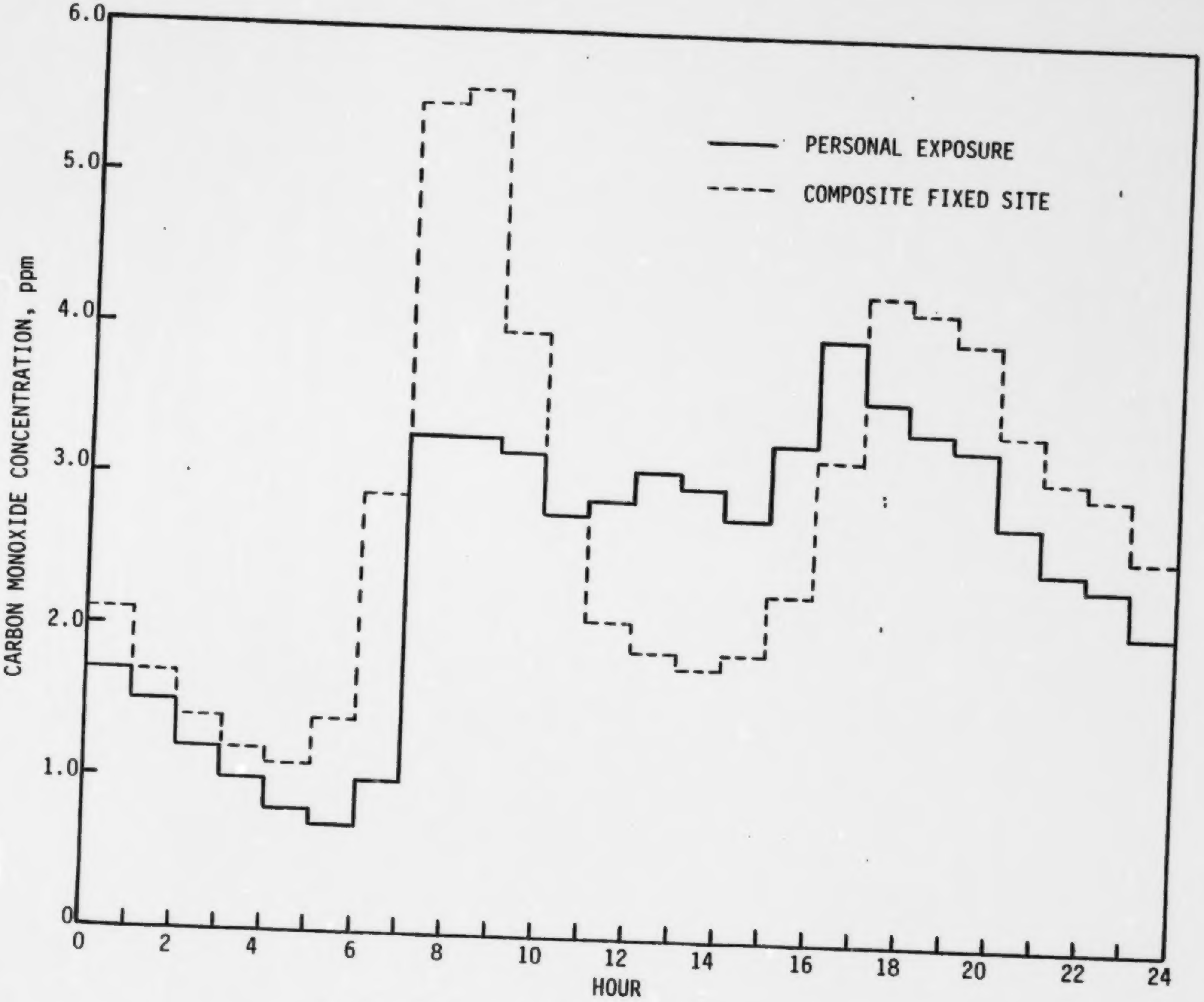

Figure 6-8. Weekday diurnal patterns.

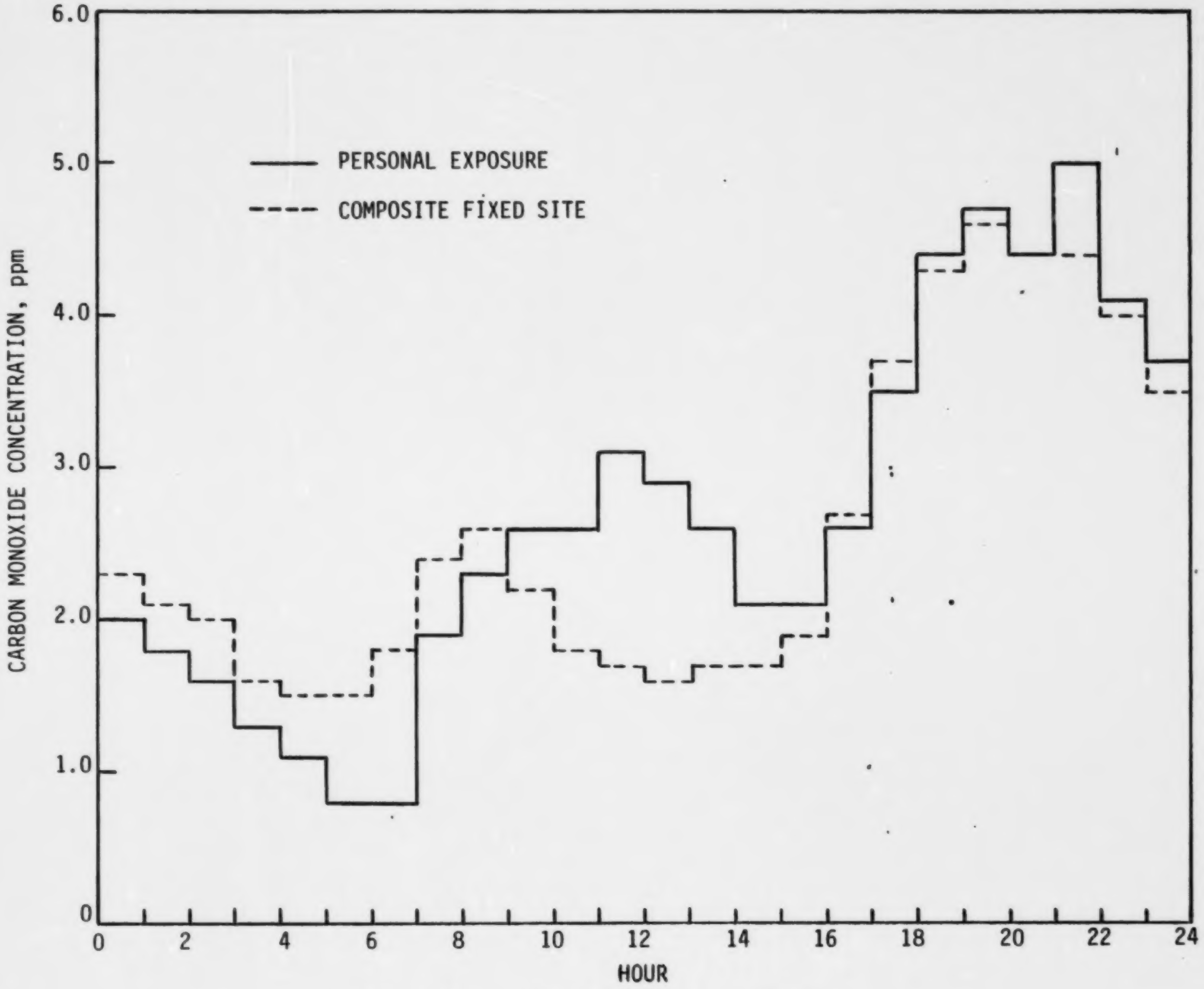

Figure 6-9. Saturday diurnal patterns.

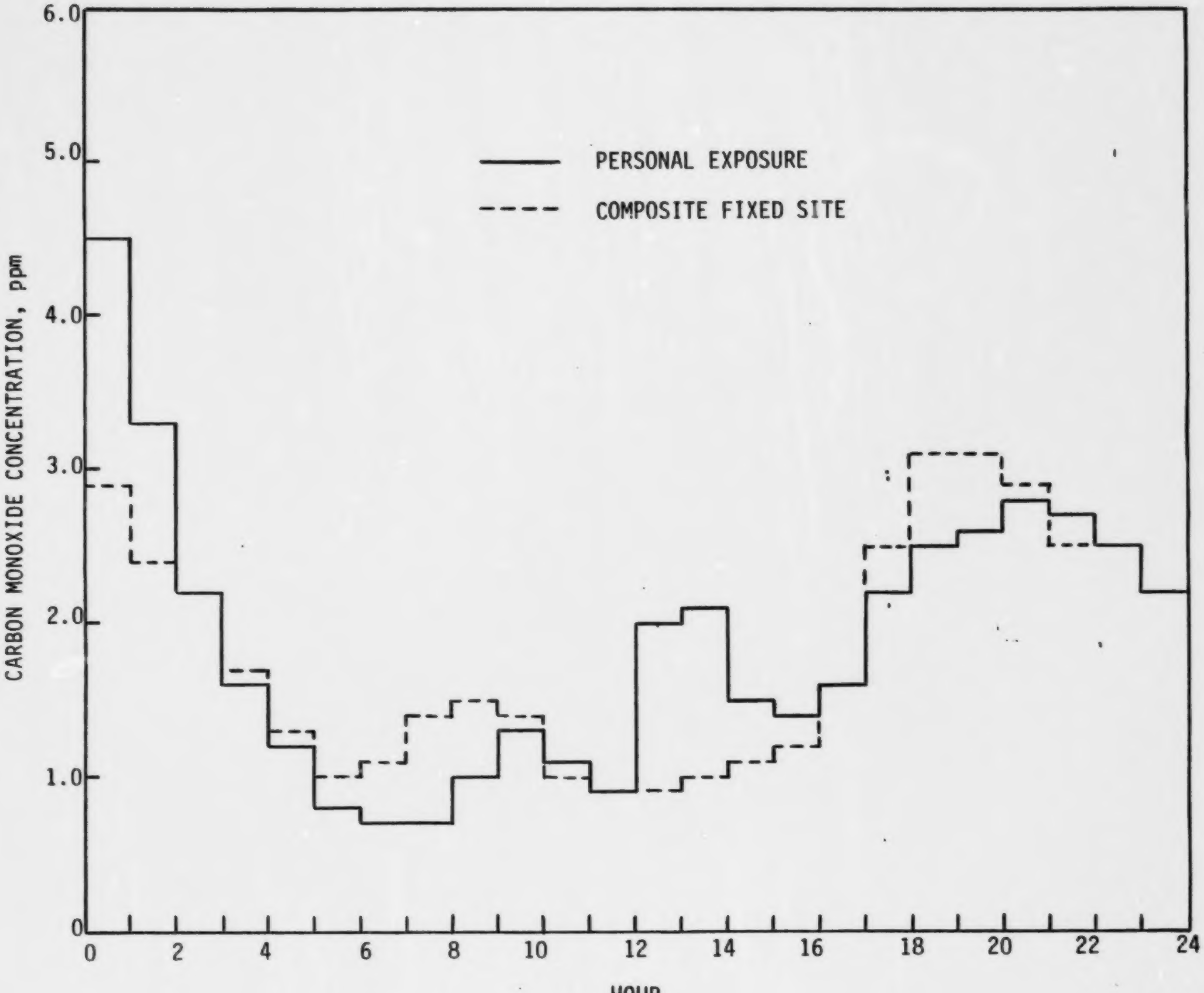

Figure 6-10. Sunday diurnal patterns.

Each of the exposure patterns in Figures 6-8, 6-9, and 6-10 represents an hour-by-hour averaging of the exposures of a large number of individuals. The result is a "smoothed" exposure pattern which does not reveal the extreme exposures experienced by some subjects in the population. For example, Figure 6-8 probably underestimates the rush-hour exposures of commuters because it is based on data obtained from commuters and noncommuters. A suggested area for future data analysis is the development of diurnal patterns for selected lifestyles such as "commuting professional," "homemaker with children," and "retiree." Individual exposure patterns can be examined using the PROFILE program described in Section 4.12.

6.11 SUGGESTIONS FOR FURTHER ANALYSIS

Sections 6.7, 6.8, and 6.9 summarize analyses relating CO exposures to selected microenvironments, to indoor sources, and to nearby fixed-site data. Many other types of analysis are possible and should be considered in future research efforts. To facilitate the selection of promising areas for analysis, PEDCo compiled a list (Table 6-27) of all potential exposure factors for which data exist, sources of these data, appropriate statistical analyses, and appropriate CO concentrations to which the analyses should be applied. For example, Table 6-27 indicates that trip density data (Factor 14) are available from a PEDCo computer file, that regression analysis should be used to determine the relationship between this factor and CO concentration, and that all PEM readings (regardless of category) can be used in the analysis. In the case of Factor 4 (mode of travel), data are obtained from the field data sheets. A linear model or analysis of variance procedure is recommended, and only PEM readings with location codes of 01 (in transit) should be analyzed. The sources of data for the various exposure factors were described in detail in Sections 3 and 5.

In many cases where the study questionnaire and the field data sheet provide data on the same exposure factor, the data provided by the field data sheet are more specific and reliable. For example, Factor 4 (mode of travel) gives the actual mode for each in-transit PEM reading, whereas Factor 28 (commute mode) gives the usual mode of commuting only. In analyses of PEM value/exposure factor relationships, PEDCo suggests that the most reliable

TABLE 6-27. POTENTIAL EXPOSURE FACTORS FOR WHICH DATA HAVE BEEN COMPILED

Factor	Source of data	Appropriate analysis	Appropriate concentration data category
1. Activity (codes 1-14)	Field data sheet	LM[a]	All[b]
2. Location	Field data sheet	LM	All
3. Census tract	Field data sheet	LM	All
4. Mode of travel	Field data sheet	LM	Location = 01
5. Attached garage	Field data sheet	LM	Indoor locations
6. Gas stove in use	Field data sheet	LM	Indoor locations
7. Smokers present	Field data sheet	LM	All
8. Time of day	Field data sheet	LM	All
9. Duration of exposure	Field data sheet	R[c]	All
10. Date	Field data sheet	LM	All
11. PID	Field data sheet	LM	All
12. Monitor number	Field data sheet	LM	All
13. RDEN[d] of census tract	PEDCo computer file	R	All
14. TDEN[e] of census tract	PEDCo computer file	R	All
15. Other traffic density factors	Data supplied by DRCOG	R,LM	All
16. Housing type	Q1, p. 12, study questionnaire	LM	Location = 02[f]
17. Living area (sq. ft.)	Q2, study questionnaire	R	Location = 02
18. Smokers in household	Q3, study questionnaire	R,LM	Location = 02
19. CO sources in residence	Q4, study questionnaire	LM	Location = 02
20. Energy-saving devices in residence	Q5, study questionnaire	LM	Location = 02
21. Fans in residence	Q6, study questionnaire	LM	Location = 02
22. Heating system in residence	Q7, study questionnaire	LM	Location = 02
23. Air conditioning in residence	Q8, study questionnaire	LM	Location = 02
24. Garage attached to residence	Q9, study questionnaire	LM	Location = 02
25. Pollution sources near residence	Q10, study questionnaire	LM	Location = 02, 51, 71, 76
26. Commute status	Q11, study questionnaire	LM	Daily avg.[g] Daily max.[h]

(continued)

TABLE 6-27 (continued)

Factor	Source of data	Appropriate analysis	Appropriate concentration data category
27. Commute duration	Q12, Q14, study questionnaire	R	Daily avg.
28. Commute mode	Q12, Q14, study questionnaire	LM	Daily avg.
29. Commute with smokers	Q12, Q14, study questionnaire	LM	Location = 01
30. Hours in motor vehicle	Q17, study questionnaire	R	Daily avg.
31. Make and model of motor vehicle	Q18, study questionnaire	LM	Mode of travel = 02
32. Hours in Q18 motor vehicle	Q19, study questionnaire	R	Daily avg.
33. Type of enclosed work area (EWA)	Q22, study questionnaire	LM	Activity = 02, indoor locations
34. Square feet in EWA	Q23, study questionnaire	R	Activity = 02, indoor locations
35. Air conditioning in EWA	Q24, study questionnaire	LM	Activity = 02, indoor locations
36. Fan in EWA	Q25, study questionnaire	LM	Activity = 02, indoor locations
37. Smokers in EWA	Q26, study questionnaire	LM	Activity = 02, indoor locations
38. Work place heating system	Q27, study questionnaire	LM	Activity = 02, indoor locations
39. Pollution sources near work	Q28, study questionnaire	LM	Activity = 02
40. Occupation type	Q29, study questionnaire	LM	Activity = 02
41. Hours working outside	Q31, study questionnaire	R	Daily avg.
42. Leisure time activities	Q32, study questionnaire	LM	Activity = 14
43. Leisure time activity location	Q32, study questionnaire	LM	Activity = 14
44. Leisure time activity duration	Q32, study questionnaire	R	Daily avg.

(continued)

TABLE 6-27 (continued)

Factor	Source of data	Appropriate analysis	Appropriate concentration data category
45. Park in indoor garage	Q33, study questionnaire	LM	Daily max.
46. Time spent in indoor garage	Q34, study questionnaire	R	Daily avg.
			Daily max.
47. Sex	Q35, study questionnaire	LM	Daily avg.
48. Age	Q35, study questionnaire	LM	Daily avg.
49. Education	Q35, study questionnaire	LM	Daily avg.
50. Construction of residence	Page 12, study questionnaire	LM	Location = 02
51. High-risk occupation	Q9, CMIQ	LM	Activity = 02
52. Stratum	RTI computer file	LM	Varies
53. Simultaneous reading at nearest fixed monitor	PEDCo computer file	R	All
54. Meteorological conditions	Data from DRCOG	LM, R	Varies

[a] Linear model/analysis of variance.

[b] All PEM readings.

[c] Regression.

[d] Residential density.

[e] Trip density.

[f] PEM readings with activity code = 02 (work or study).

[g] Mean value of 24-hour sampling period.

[h] Largest 1-hour value during 24-hour sampling period.

exposure factor be used if two or more alternatives exist. PEDCo further suggests that exposure factors which are not expected to significantly affect CO exposure receive lower priority during data analysis. Such factors include 12 (monitor number), 31 (make of vehicle), 48 (age), and 49 (education).

PEDCo's evaluation suggests that the following factors are either redundant, unreliable, or relatively insignificant: 12, 31, 24, 26-32, 36, 41-46, 48, and 49. The remaining factors have been divided into Groups A and B (Table 6-28). Analysis of Group A factors is considered more desirable than analysis of Group B factors. Specific data analyses that PEDCo believes would be particularly useful include:

1. Analysis of variance (ANOVA) of exposure by activity code.
2. Additional comparisons of exposures in selected microenvironments with and without selected CO sources (e.g., gas stoves) to determine contribution of each source to exposure.
3. Estimation of average time spent per person in each microenvironment and development of typical activity patterns for persons with selected demographic characteristics.

TABLE 6-28. POTENTIAL EXPOSURE FACTORS IN GROUPS A AND B

Group A	Group B
1. Activity	3. Census tract
2. Location	9. Duration
4. Mode of travel	10. Date
5. Attached garage	11. PID
6. Gas stove in use	16. Housing type
7. Smokers present	17. Living area (sq ft)
8. Time of day	18. Smokers in household
13. RDEN of census tract	20. Energy-saving devices in residence
14. TDEN of census tract	23. Air-conditioning in residence
15. Other traffic density factors	25. Pollution sources near residence
19. CO sources in residence	33. Type of enclosed work area (EWA)
22. Heating system in residence	34. Square feet in EWA
38. Work place heating system	35. Air conditioning in EWA
47. Sex	37. Smokers in EWA
52. Stratum	39. Pollution sources near work
53. Simultaneous reading at nearest fixed monitor	40. Occupation type
54. Meteorological conditions	50. Construction of residence
	51. High-risk occupation

4. Regression analysis pairing each PEM value in a particular microenvironment with residential density and/or traffic density of occupied census tract.

5. Analysis of the variation in PEM values for a particular microenvironment with duration of measurement (i.e., averaging time).

6. ANOVA of exposure by occupation, particularly high-risk versus low-risk occupations.

7. Regression analysis and/or ANOVA relating individual PEM values, daily maximum 1-hour values, or daily maximum 8-hour values with selected meteorological parameters. The necessary meteorological data can be acquired from the National Weather Service and the local PROFS network in Denver.

8. Evaluation of data items to determine which should be retained in future personal monitoring studies.

9. Development of methodology for predicting in-transit exposures from data recorded simultaneously at one or more fixed-site monitors.

10. Comparison of exposures reported for each subject's two sampling periods to determine magnitude of day-to-day variation.

11. Analysis of PEM failure frequencies with respect to selected meteorological parameters (e.g., daily mean temperature, daily low temperature) to identify possible cause(s) of failures.

12. Identification of fixed-site monitors which best represent personal exposures of Denver target population.

Analyses of the relationship between personal exposure and breath CO concentration, an indicator of carboxyhemoglobin levels, have been performed by Thomas, et al.[6]

6.12 REFERENCES

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SECTION 7

STUDY CONCLUSIONS AND RECOMMENDATIONS

In developing and implementing the Denver study, the attempt was made to investigate the appropriateness of a general approach to determining the exposure of a large urban population. The overall success of the Denver study suggests that the approach is valid. The study has also provided a rich data base that should prove invaluable in answering questions concerning the factors which affect exposure, the ability of fixed-site data to represent personal exposures, the performance of newly-developed instruments, and similar issues. This section provides a synopsis of the methods used for sample selection and data collection in the Denver study, a summary of the study results, and recommendations for improving study design and implementation. Recommendations for additional data analyses were provided in Section 6.11.

7.1 SAMPLE SELECTION AND DATA COLLECTION

The target population of the study included all noninstitutionalized, nonsmoking residents of the urbanized portion of the Denver, Colorado, metropolitan area who were between 18 and 70 years of age at the time of the study. Research Triangle Institute (RTI) developed a two-phase scheme for sampling this population, which is estimated to be 245,000. In the first phase, a two-stage sample of housing units was selected. Data on the individuals residing within these housing units were collected using a brief screening questionnaire administered by telephone or in the field. Individuals who exhibited rare characteristics with respect to CO exposure were identified and over-sampled in the second-phase of sample selection.

Individuals entered the sample by three paths. The majority of study participants (402) were identified by means of a telephone screening questionnaire administered to members of housing units appearing on a list prepared by Donnelley Marketing Information Services. The remaining 52 study participants were identified by field screening of housing units which

(1) appeared on the Donnelley list but for which no telephone number was available or (2) were identified through a special survey of housing units which did not appear on the Donnelley list. The original sample selection protocol was designed to yield 500 study participants. The reduced sample size (454) resulted from a higher than expected refusal rate and unexpected equipment problems early in the study.

The data collection instruments used in the Denver CO study included three questionnaires (screening, CMIQ, and study) which provided background data on subjects and their families, a network of 15 fixed-site monitors, the PEM's and activity diaries carried by each subject, and breath sample bags. The screening questionnaire was administered on a household basis as a means of identifying persons eligible for the study. It requested the name of each household member, relationship to head of household, sex, age, smoking status, occupation, and typical commute time. The completed screening questionnaires yielded a list of 2232 eligible individuals from which were selected a stratified sample of 1139 potential subjects. An attempt was made to administer the computer model input questionnaire (CMIQ) to each potential subject. Part A of the CMIQ requested detailed data about the commuting habits of the respondent's household and determined if any member of the household was employed in one of nine occupational categories associated with high CO exposure. These data were collected for use in SHAPE, a population exposure model developed by Wayne Ott, and NEM, a population exposure model developed by the Strategies and Air Standards Division of EPA. Part B of the CMIQ verified the respondent's address and attempted to set up an appointment for the first visit by an interviewer. The study questionnaire was administered to each of 454 persons who actually participated in the study. It included detailed questions about the subject's home environment, work environment, commuting habits, occupation, leisure-time activities, and shopping habits. The study questionnaire also requested age, sex, and education data.

A PEM and an activity diary were provided to each subject for each of two consecutive 24-hour periods. The PEM was a modified General Electric (GE) Carbon Monoxide Detector, Model 15EC53003, mated with a modified Magus DL-1 Data Logger and mounted in a compact, tamperproof casing. The PEM recorded the time and a CO concentration value every time the "activity button" on the top of the instrument was pushed and every hour on the hour. In both cases, the CO value was the integrated average CO concentration since the last recorded value. Each PEM was capable of operating continuously for 24 hours and logging up to 113 data points. Quality assurance activities associated with the PEM's included daily zero-span checks, frequent multipoint calibrations, special studies evaluating precision, and two independent audits.

The activity diary contained instructions for completing the diary, examples of properly completed diary pages, and 64 blank pages for recording activities. The subject was instructed to fill out a diary page whenever the subject changed location or activity. Data entered on each diary page included activity (e.g., cooking dinner), location (e.g., indoors - residence), address, mode of transit if applicable, and whether or not there were smokers present. For indoor locations, subjects indicated whether a garage was attached to the building and whether a gas stove was in use.

Thirteen interviewers were employed during the course of this study to deliver PEM's, activity diaries, and study questionnaires to the subjects according to prescheduled appointments. Because different PEM's and activity diaries were used for the two sampling periods, an interviewer visited each subject on three consecutive days. In most cases, the first PEM and activity diary were delivered between 7 p.m. and 9 p.m. on Day A and picked up 24 hours later on Day B. During pickup, problems encountered during the first sampling period were addressed and a second PEM and a second activity diary were delivered. These were picked up 24 hours later on Day C. Breath samples were taken during pickups on Days B and C. A study questionnaire was delivered on Day A and picked up on Day C.

A field data sheet was used to record the PEM values and corresponding coded activity diary data for each subject-day. These sheets were validated using a special computer program which checked for 83 different types of data anomalies, including missing entries, illegal entries, and logical inconsistencies.

Breath samples were taken by having each subject blow through a disposable mouthpiece into a 600 ml plastic carboxyhemoglobin bag. To measure the CO concentration of the breath sample, a prefilter containing potassium permanganate and activated carbon was inserted between the mouthpiece and a General Electric CO-3 portable CO monitor.

Fifteen fixed-site monitors operated in Denver during the period of the study. Nine of these monitors were temporary and were discontinued at the conclusion of the study. All of the monitors reported hourly-average CO data and operated continuously.

7.2 STUDY RESULTS

A total of 1094 subject-days of participation were scheduled. The 454 individuals who actually participated in the study yielded 900 subject-days; 446 subjects participated in two sampling periods, while 8 subjects participated in only one sampling period. Of the remaining 194 subject-days scheduled, 120 were lost because subjects requested rescheduling, 33 were lost because of last-minute refusals to participate, and 41 were lost for other reasons (e.g., subject missed appointment, interviewer experienced car problems).

Of 899 subject-days of data obtained from the participants, 808 (90%) were coded as acceptable for statistical analysis of PEM values. Of the remaining 91 subject-days, 50 were coded as unacceptable because the difference between pre and post zero-span values was judged excessive. Other frequently occurring instrument problems included clogged pumps, low battery voltage, instances when the PEM logic system switched out of the data-recording mode, and fragile parts.

Multipoint calibrations performed early in the study revealed a potential nonlinearity problem in the low concentration portion of the PEM's operating range. The adverse effects of this nonlinearity on the overall data quality were minimized by insuring that the PEM GE sensor outputs were properly balanced to the output of the Magus data subsystem outputs.

The accuracy of PEM measurements was determined daily based on a pre- and post-sampling check of zero and span. Using the change in slope as a measure of accuracy, 93 percent of the measurements are estimated to be within ±5 percent of the true concentration value. PEM's operated in pairs showed a mean percent difference in paired values of 5.0 percent with a standard deviation of 14.2 percent. PEM's attached to manifolds supplying sample ambient air to fixed-site monitors yielded paired values with a mean difference of 8.3 percent (fixed site being higher) and a standard deviation of 22 percent.

A total of 859 subject-days (96%) were coded as acceptable for statistical analysis of activity diary entries. In addition, 778 subject-days (87%) were coded as acceptable for statistical analyses involving both PEM and activity diary data.

A total of 859 breath samples were obtained and successfully analyzed for CO content. Thirty samples were lost because of leaks in the sample bag. One subject refused to provide a breath sample, and another was unable to provide a sample because of illness. Nine samples were not obtained for other reasons (e.g., subject could not fill breath bag).

The highest 1-hour CO concentration reported by any of the 15 fixed-site monitors during the study period was 44.1 ppm. Only one fixed-site monitor (060580002F01) reported daily maximum 1-hour values exceeding 35 ppm, the level of the current 1-hour NAAQS. The highest 8-hour CO concentration reported by any of the 15 fixed-site monitors was 20.7 ppm. Eleven of the 15 fixed-site monitors reported daily maximum 8-hour values exceeding 9 ppm, the level of the current 8-hour NAAQS. Five fixed-site monitors reported daily maximum 8-hour values exceeding 15 ppm.

The daily maximum 1-hour and 8-hour exposures calculated for the study sample were extrapolated to the Denver target population using weighting factors which accounted for the probability of selecting a particular subject into the sample and for nonresponse caused by refusals, instrument problems, and unacceptable activity diary data. The weighted means for daily maximum 1-hour and 8-hour exposures during the study period were 10.3 ppm and 4.9 ppm, respectively. Approximately 3 percent of the daily maximum 1-hour exposures exceeded 35 ppm; approximately 11 percent of the daily maximum 8-hour exposures exceeded 9 ppm.

Weighted linear regression analyses of the daily maximum 1-hour and 8-hour exposures predict that a member of the Denver target population who receives a daily maximum 8-hour exposure of 9 ppm would receive a daily maximum 1-hour exposure of 16.3 ppm. Similarly, a person receiving a daily maximum 1-hour exposure of 35 ppm would receive a daily maximum 8-hour exposure of 16.1 ppm.

Using valid individual PEM values with durations of 60 minutes or less, the weighted means and standard deviations of PEM values grouped by microenvironment code were calculated. Listing the microenvironments in descending order by mean CO concentration suggests that microenvironments associated with motor vehicles had the highest CO levels in Denver during the study period.

Occupancy period was defined as the time a subject spends in a microenvironment during a single visit. Mean occupancy periods for in-transit microenvironments associated with motor vehicles and high CO levels were 30.8 minutes for trucks, 28.0 minutes for buses, 25.9 minutes for cars, and 23.0 minutes for motorcycles.

An analysis was conducted of residential indoor exposures to determine the contribution of three potential CO sources. Mean exposure was increased 2.59 ppm by gas stove operation, 1.59 ppm by smokers, and 0.41 ppm by attached garages.

Some models used for estimating population exposure assume that a strong, linear relationship exists between CO levels in certain microenvironments and CO levels measured simultaneously at fixed-site monitors. This assumption was investigated by performing linear regression analyses that used PEM values grouped by microenvironment as the dependent variable and fixed-site values as the independent variable. For in-transit microenvironments, the independent variable was the mean of the simultaneously-recorded values at all 15 sites. For nontransit microenvironments, the independent variable was the simultaneously-recorded value at the nearest fixed-site monitor. Coefficients of determination (R^2) ranged from 0 to 0.58. Most were less than 0.50. Microenvironments with R^2 values exceeding 0.30 included parks and golf courses, motorcycles, and buses. The residential garage microenvironment yielded an R^2 value of zero.

Diurnal patterns for weekdays, Saturdays, and Sundays were developed for hourly average exposures and composite fixed-site values. In general, diurnal patterns for exposure were similar in shape to those for fixed-site data, although the exposure patterns contained midday peaks missing from the fixed-site patterns.

The various analyses discussed above are only a small fraction of those that could be performed on the rich data base created by the Denver study. Recommendations for further data analysis are provided in Section 6.11.

7.3 RECOMMENDATIONS FOR IMPROVING STUDY DESIGN AND IMPLEMENTATION

An evaluation of the problems encountered during sample selection and data collection suggests several areas where the design and implementation of future studies could be improved.

7.3.1 Sample Selection

Table 6-8 provides a profile of the study participants with respect to their responses to selected data items on the study questionnaire. Because certain population groups were deliberately oversampled in developing the stratified sample discussed in Section 2.3, Table 6-8 is not expected to reflect the actual breakdown of these characteristics in the general Denver population. Furthermore, the requirement that subjects be nonsmokers and between the ages of 18 and 70 further biases the sample away from the general Denver population. One apparent result of these sampling biases is that women comprise 62.8 percent of the sample. The Bureau of Census (BOC) estimates that 52.3 percent of adults 18 to 65 years of age in the Denver SMSA are female. The higher proportion of women in the sample may be partly the result of excluding smokers and including adults 65 to 70 years of age. In addition, women as a group may be less reluctant than men to participate in a study that requires carrying a personal monitor. An analysis to determine the relative significance of these factors has not been attempted. Consequently, it is uncertain whether the weighting factors described in Section 2.4 will remove all sample bias connected with sex in extrapolations to the Denver target population. Future research should address this problem by determining the principal cause of the bias and then taking appropriate steps to reduce the bias. For example, an extra effort could be made to solicit male subjects during telephone interviews. If this was unsuccessful, post-stratification adjustments based on census data could be made to the weighting factors.

The results in Table 6-20 suggest high CO exposures are associated with public garages, motorcycles, service stations, and buses. However, relatively few PEM measurements were taken in these microenvironments. To better characterize these exposures, future studies should oversample persons who regularly occupy these microenvironments.

7.3.2 Data Collection

The format of the data entry pages in the activity diary should be revised to better capture high exposure situations. The responses "indoors, residential garage" and "indoors, other garage" should be added to the alternatives under LOCATION. Since a subject's activities are wholly characterized by the activity diary, the instructions should specify that the subject fill out a new page whenever a change in his activities or surroundings would change one or more entries on the most current diary page.

Problems encountered in the design and operation of the PEM's were discussed in Section 6.3 and Appendix N. Recommendations for correcting the more serious problems include

1. incorporating the balance check described in Section 6.3.1 as part of the multipoint calibrations,
2. changing the PEM data subsystem to permit storage of negative concentration values,
3. identification and correction of the cause of decrease in PEM sensitivity with time,
4. inverting the scrubber column,
5. identification and correction of the causes of the PEM "lock-up" and mode-switching problems, and
6. elimination of fragile solder joints.

The use of a PEM with facilities for direct entry of activity codes has been proposed for future studies. Although such a PEM was not used in this study, it is apparent that activity data stored in such an instrument would be difficult to validate and subject to loss whenever the PEM power supply malfunctioned. In addition, the correction of data entry errors by subjects would be difficult. Finally, the use of "fill-in-the-blank" data items such as ADDRESS and "other indoor location" under LOCATION would be prohibited. The ADDRESS data item was invaluable in analyzing the relationship between CO concentrations measured simultaneously by PEM's and nearby fixed-site monitors. Thus, the use of direct-entry PEM's would appear to be appropriate only in those studies which require minimal data validation, permit some loss of activity data, and do not require fill-in-the-blank data entries. Such a study would almost certainly provide a less detailed data base than that provided by the Denver study.

APPENDIX A

FIELD SCREENING QUESTIONNAIRE AND INSTRUCTIONS

OMB No.: 2080-0003
Expires: September 1983

STUDY OF CARBON MONOXIDE EXPOSURE
HOUSEHOLD SCREENING QUESTIONNAIRE - FIELD VERSION

CASE # ____________________

FIELD INTERVIEWER ID # __________

Hello. My name is ______________ from Colorado Market Research in Denver, Colorado. We are conducting a study for the Environmental Protection Agency and your household has been randomly selected along with others in this area to be interviewed.

I need to speak to a resident of this household who is 16 years old or older. Are you a resident of the household?

☐ Yes → CONTINUE
☐ No
↓

ASK TO SPEAK TO A RESIDENT WHO IS 16 OR OLDER. IF NO ONE IS AVAILABLE, OBTAIN TELEPHONE NUMBER AND TERMINATE INTERVIEW.

Telephone Number: (________) ________ - ______________
Area Code

Are you 16 years old or older?

☐ Yes → CONTINUE UNLESS RESPONDENT OBVIOUSLY CANNOT GIVE REQUIRED INFORMATION; IF RESPONDENT IS INCAPABLE:
↓
☐ No
↓

ASK TO SPEAK TO ANOTHER RESIDENT WHO IS 16 OR OLDER. IF NO ONE IS AVAILABLE, OBTAIN TELEPHONE NUMBER AND TERMINATE INTERVIEW.

Telephone Number: (________) ________ - ______________
Area Code

As I mentioned earlier, I am here in connection with a study we are conducting for the Environmental Protection Agency that deals with the amount of carbon monoxide to which people are exposed. Your participation is voluntary and the data that you provide will be kept strictly confidential. Any release of the data will be in summary form only. This part of the study will take only a few minutes of your time. I would like to obtain the first name of each person living in the household.

1. a. First, what is the first name of the person who is the head of the household?

ENTER BENEATH "01" IN COLUMN 1.

b. What are the first names of the other people who live in the household?

ENTER BENEATH HOUSEHOLD MEMBER NUMBERS IN COLUMN 1. DETERMINE RESPONDENT AND INDICATE BY CIRCLING HOUSEHOLD MEMBER NUMBER IN COLUMN 1.

c. I have listed (READ NAMES). Is there anyone else living here now, such as friends, relatives, or roomers?

IF YES, ADD TO ROSTER.

d. Do any of these people have a permanent residence somewhere else?

IF YES, DETERMINE WHICH PERSON(S) AND DELETE FROM ROSTER.

e. Do any of these people plan to move from this residence in the next two months?

IF YES, DETERMINE WHICH PERSON(S) AND DELETE FROM ROSTER. IF ENTIRE HOUSEHOLD PLANS TO MOVE, THANK RESPONDENT AND TERMINATE.

Now, I need a little information about each person.

ASK QUESTIONS 3-7 FOR HEAD OF HOUSEHOLD, THEN ASK QUESTIONS 2-7 AS APPLICABLE FOR ALL OTHER PERSONS ON ROSTER.

2. DO NOT ASK FOR HEAD OF HOUSEHOLD.
How is (NAME) related to (HEAD OF HOUSEHOLD)?

ENTER ONE OF THE FOLLOWING CODES IN COLUMN 2.

Spouse	02
Child	03
Other relative	04
Not related	05

ALSO ENTER "M" OR "F" IN COLUMN 3; ASK Q. 3 ONLY IF SEX NOT OBVIOUS BY NAME OR DESCRIPTION.

3. Is (NAME) male or female?

4. How old was (NAME) on (his/her) last birthday?

ENTER AGE IN COLUMN 4.

FOR EACH PERSON 18 YEARS OF AGE OR OLDER, ASK QUESTIONS 5, 6, AND 7.

5. Does (NAME) presently smoke or use tobacco in any form?

   IF "YES," ENTER "Y" IN COLUMN 5.
   IF "NO," ENTER "N" IN COLUMN 5.

6. Is (NAME) employed either full or part time?

   IF "YES," PROBE FOR PRECISE OCCUPATION AND ENTER IN COLUMN 6.
   IF "NO," DETERMINE WHAT PERSON DOES AND DESCRIBE IN COLUMN 6.

7. Does (NAME) travel to and from work, school, or any other place at least three times a week?

   IF "NO" - ENTER ZEROES IN COLUMN 7.
   IF "YES," ASK: How much time does (he/she) spend traveling one way?
   ENTER IN COLUMN 7.

Now, a few final questions.

8. In your household, is there:

		Yes	No
a.	a fire place which is used	1	2
b.	a wood stove	1	2
c.	a gas furnace	1	2
d.	a gas cooking stove	1	2
e.	a gas hot water heater	1	2
f.	a gas clothes dryer	1	2
g.	a gas or kerosene space heater	1	2
	Are there any other gas appliances?	1	2

SPECIFY:

9. Does your household have an attached garage, or share a multi-family garage?

☐ Attached

☐ Multi-family

☐ Neither

Thank you very much for your help.

The information that you and other persons in the area have provided will help us in planning the next phase of this study of carbon monoxide in the Denver area. Based on this information, a random sample of individuals will be selected to participate in the main study. People who are selected will be called by our telephone interviewers. What is the telephone number here? We hope that you will be willing to help us if you are selected. Have a good (day/evening). Goodbye.

Telephone Number: (________) ________ - ____________________
Area Code

☐ Telephone Number Refused

☐ No Telephone

PROVIDE THE FOLLOWING INFORMATION ONLY IF ASKED.

People who are selected for the main study will be asked to carry a small portable monitor about the size of a small camera case for a specified 24-hour period to measure their exposure to carbon monoxide during that period. Participants will be paid a small amount for helping with this part of the study.

				ANSWER ONLY FOR PERSONS 18 YEARS OLD OR OLDER.		
1	2	3	4	5	6	7
Household Member	Relation to Head	Sex	Age	Smoker?	Occupation	Time Spent Commuting
01	01					___ hr. ___ min.
02						___ hr. ___ min.
03						___ hr. ___ min.
04						___ hr. ___ min.
05						___ hr. ___ min.
06						___ hr. ___ min.
07						___ hr. ___ min.
08						___ hr. ___ min.
09						___ hr. ___ min.
10						___ hr. ___ min.
11						___ hr. ___ min.
12						___ hr. ___ min.
13						___ hr. ___ min.

ADMINISTERING THE HOUSEHOLD SCREENING QUESTIONNAIRE

FIELD VERSION

The purpose of this questionnaire is to obtain a list of the household residents, certain information about these persons, and information on the presence of gas appliances and attached garages. The information will be used to select individuals who will be asked to use the PEM.

The instructions necessary to complete the interview are incorporated in the questionnaire, which is printed in the following format:

- All questions and statements that are to be read to the respondent are printed in upper and lower case letters.
- All instructions for the interviewer are printed in UPPER CASE LETTERS. These are only for the interviewer; they are not to be read to the respondent.

FOLLOW EACH INSTRUCTION CAREFULLY!

Failure to follow instructions can result in confusion for you and for the respondent, and consequently in missing or inadequate information.

During the interview you will obtain information about certain members of the household. All questions are worded for that purpose. You should reword questions as necessary to avoid an awkward conversation. For example, when asking about the respondent, questions should be asked "Do you ..." rather than "Does (NAME) ...". In a single person household, all questions should refer to "you."

1. Determining Eligibility

For this questionnaire, an "eligible" respondent is:

- a member of the household
- sixteen years old or older
- mentally and physically capable of giving the required information.

Questions and instructions are printed in the questionnaire as a guide in reaching an eligible respondent; included is a brief introductory statement for the interviewer. The questions are:

- A question to determine if the person you are talking to is a resident of the household:

  "Are you a resident of the household?"

  If not, ask to speak to a resident who is 16 or older; if no one available, obtain telephone number and terminate the interview.
- A question to determine if the person you are talking to is 16 or older:

  "Are you 16 years old or older?"

  If not, or person obviously is mentally or physically incapable of giving the required information, ask to speak to another household member who is 16 years old or older. If no one is available, obtain telephone number and terminate the interview.

  When an eligible respondent has been reached, read the introduction to the study and continue with Question 1.

2. Question-By-Question Specifications

As indicated previously, the instructions necessary to complete the interview are printed in the questionnaire. A few additional instructions and clarifications for some items are given here.

Questions 1.a.-1.e. -- Determining Household Roster

The purpose of this question is to determine the household members about whom Questions 2 through 7 are to be asked. Names of household members are needed only for the purpose of asking applicable questions about each person. Be sure to emphasize the work first when asking for names. The list of names is called the household roster.

If the respondent refuses to give names but will cooperate otherwise, enter "RE" in column 1 to account for all persons in the household; ask Questions 2 through 7 for "Person 1, Person 2," etc.

Question 1.a. --

"First, what is the first name of the person who is the head of the household?"

The head of the household is the person the respondent considers the head of the household. If the respondent considers no one as head of the household (as in an apartment shared by three persons), ask for respondent's first name and enter as person 01 in column 1.

Question 1.b. --

"What are the first names of the other people who live in the household?"

Names of other persons who live in the household may be entered in column 1 in any order. The important thing is to be sure you have accounted for all persons who live there.

Identifying Respondent

After the names of all household members have been entered, circle the household member number of the respondent in column 1; if you have not determined the name of the person you are talking to, ask respondent for his/her name.

Question 1.c. --

"I have listed (READ NAMES). Is there anyone else staying here now, such as friends, relatives, or roomers?"

This question is intended to assure that all persons who live in the household have been accounted for. Persons temporarily visiting the household are not to be considered as "living" there. If the answer to the question is "Yes," ask for the first names of such persons and add them to the household roster.

Question 1.d. --

"Do any of these people have a permanent residence somewhere else?"

If a person has a permanent residence somewhere else, that person is to be deleted from the roster; he/she is not considered a member of this household. If a person has two permanent residences, he/she is considered a member of this household only if he/she spends the majority of the time in this household. If the answer to this question is "Yes," determine which person(s) and delete person(s) from roster by drawing a line through the name(s).

Question 1.e. --

"Do any of these people plan to move from this residence in the next two months?"

The purpose of this question is to identify persons eligible to be selected for the main study. If a person plans to leave the household before the main study is completed, that person is not eligible to participate. Since persons for the main study are selected from household rosters, ineligible persons must be deleted from the roster by this question. If the answer is "Yes," determine which person(s) plan to move and delete from roster. If the entire household plans to move, no one in the household is eligible for the field phase of the study. Thank the respondent and terminate the interview.

Question 2 --

"How is (NAME) related to (NAME OF HEAD OF HOUSEHOLD)?"

Do not read this question for the first person on the roster. For all other persons, ask the question and enter the appropriate code in column 2.

Question 3 --

"Is (NAME) male or female?"

Enter "M" or "F" in column 3. If the sex of a person is obvious from name or description, do not ask the question.

Question 4 --

"How old was (NAME) on (his/her) last birthday?"

Enter age of person on last birthday in column 4. NOTE: Children under one year of age were "0" years old on last birthday; thus, for a child said to be eight months, you will enter "0" as the age.

NOTE: QUESTIONS 5, 6, AND 7 ARE ASKED ONLY FOR PERSONS 18 YEARS OF AGE OR OLDER.

Question 5 --

"Does (NAME) presently smoke or use tobacco in any form?"

Enter "Y" (YES) or "N" (NO) in column 5, as appropriate.

Question 6 --

"Is (NAME) employed either full or part time?"

Regardless of the answer to this question, you must ask additional questions to determine the occupation, if employed, or the main activity of the person; do not enter an occupation and an activity in column 6. Occupation takes preference over activity even though more time is spent in the activity. If the person is employed either full-time or part-time, get as much information as necessary to determine and enter the exact occupation. If a person has more than one job, enter the occupation considered to be the main one; if no "main" one, enter the occupation at which the person spends the most time.

If the person is not employed, enter the person's main activity, such as "Housewife, Student, etc."

Question 7 --

"Does (NAME) travel to and from work, school, or any other place at least three times a week?" If Yes: "How much time does (he/she) spend traveling one way?"

This question refers to trips made to one place on a regular basis; it does not include incidental trips to run errands. Be sure to include trips of persons who are transported by someone else, such as disabled persons taken for treatments, etc.

If the answer is "Yes," ask the follow-up question and enter the answer as "0 hours, 10 minutes" or "1 hour, 0 minutes," etc. If a person travels to more than one place on a regular basis, determine and enter time for the one-way trip that requires the longest time.

If the answer is "No," enter zeroes in column 7.

Question 8 --

"In your household, is there

a. a fireplace which is used
b. a wood stove
c. a gas furnace
d. a gas cooking stove

e. a gas hot water heater

f. a gas clothes dryer

g. a gas or kerosene space heater

Are there any other gas appliances?"

Ask parts a. through g. and circle the correct code for each. If the answer to the last question is "Yes," enter all other gas appliances in the space provided. This question refers to appliances in the household; it does not include outside gas appliances. If you are unsure of whether to include an appliance, enter it together with location or other descriptive information.

Question 9 --

"Does your household have an attached garage, or share a multi-family garage?"

If the answer is "Yes," determine whether the garage is attached or shared and check the appropriate box. If garage is both attached and shared, check the box for "attached;" attached takes precedence over multi-family. If the answer is "No," check the box beside "Neither."

Terminate Interview

Read the closing remarks, obtain the telephone number, and thank the respondent for his/her time.

APPENDIX B

COMPUTER MODEL INPUT QUESTIONNAIRE

OMB No.: 2080-0003
Expires: September 1983

COMPUTER MODEL INPUT QUESTIONNAIRE

DENVER CO STUDY

October 1982

Study of Carbon Monoxide Exposure
Computer Model Input Questionnaire

Case #: ____________________

Telephone #: (____) ____________

FI ID #: ____________________

A.1 Hello. My name is ____________________ from Colorado Market Research in Denver, Colorado. May I speak to ____________________ (Respondent)?

IS RESPONDENT AVAILABLE?

☐ YES → GO TO A.3

☐ NO → CONTINUE WITH A.2

A.2 SCHEDULE A CALLBACK BY ASKING FOR THE BEST TIME AND DAY TO CALL BACK WHEN RESPONDENT WILL BE AVAILABLE.

RECORD THE CALLBACK INFORMATION IN THE COMMENT SECTION OF THE RECORD OF CALLS SECTION ON THE CONTROL CARD.

A.3 IS THIS AN APPOINTMENT?

☐ YES → GO TO A.7

☐ NO → CONTINUE WITH A.4

A.4 Several weeks ago we contacted your household and asked a few questions as the first part of a study sponsored by the U.S. Environmental Protection Agency. This study is an attempt to describe exposure to carbon monoxide of people in your area. We are now beginning the main part of the study and you have been selected to participate.

CONTINUE WITH A.5

A.5 In the main part of the study we will be actually measuring exposure to carbon monoxide and relating it to activities in which people participate. To do this, we are asking you and 500 other people to carry a small monitor that will measure carbon monoxide exposure for two 24-hour periods and to list all activities during that period. We are also asking each selected person to participate in a short telephone interview and to complete a longer questionnaire sometime during the two 24-hour periods the monitor is being used. Each person who participates in this part of the study will be paid $11. Your participation is voluntary and the data that you provide will be kept confidential.

Is it convenient for you to do the short telephone interview now?

☐ YES → GO TO A.7

☐ NO → CONTINUE WITH A.6

A.6 When will be a better time to call back?

ENTER TIME AND DAY OF APPOINTMENT IN THE COMMENT SECTION OF THE RECORD OF CALLS SECTION ON THE CONTROL FORM.

Thank you for your time. I will call you again on (READ DAY AND TIME OF APPOINTMENT).

Goodbye.

A.7 When we first called your household about this study, we determined that the following individuals lived in your household: (READ NAMES IN COLUMN 1).

Do all of these people still live in the household?

☐ YES → GO TO A.10

☐ NO → CONTINUE WITH A.8

A.8 DETERMINE WHICH OF THESE PERSONS NO LONGER LIVES IN THE HOUSEHOLD. DELETE PERSON(S) FROM ROSTER BY DRAWING A LINE THROUGH THE NAME(S).

A.9 Now I have listed the following people who still live in your household: (READ NAMES REMAINING IN COLUMN 1).

Do these people still live there?

☐ YES → CONTINUE WITH A.10

☐ NO → RETURN TO A.8

A.10 The purpose of this interview is to collect information about the trips each household member makes each week. Lets start with (FIRST NAME ON ROSTER).

ASK QUESTIONS 1-7 AS APPLICABLE FOR ALL PERSONS ON THE ROSTER, THEN CONTINUE WITH QUESTION 8.

1. Does (NAME) commute at least three times a week to work, school, or any other place?

YES → ENTER "1" IN COLUMN 1 AND CONTINUE WITH QUESTION 2.
NO → ENTER "2" IN COLUMN 1 AND GO TO QUESTION 5.

2. By what means of transportation does (NAME) usually travel on these trips?

RECORD IN COLUMN 2. IF MULTIPLE MODES GIVEN, LIST IN ORDER OF USE. RECORD UP TO 3 MODES.

3. In a typical one-way trip, how many minutes does (NAME) spend in the (MODE OF TRANSPORTATION FROM COLUMN 2)?

RECORD IN COLUMN 3. IF MULTIPLE MODES OF TRANSPORT, OBTAIN TIME FOR EACH.

4. In a typical one-way trip, how many miles does (NAME) travel?

RECORD IN COLUMN 4.

5. In a normal week, how many (other) trips does (NAME) take, such as a trip to the store, or out to lunch, or going for a drive, either alone or with someone else? (These are trips that (NAME) takes other than the ones you have already told me about.)

RECORD IN COLUMN 5. IF ZERO, GO TO QUESTION 7.

6. On these (NUMBER FROM Q. 5) trips, how many total minutes does (NAME) spend traveling both ways?

RECORD IN COLUMN 6.

7. DO NOT ASK FOR PERSON IF "NO" TO QUESTION 1 AND "0" TO QUESTION 5.

a. Where does (NAME) normally park when away from home--on the street or in a parking lot or garage?

CODE COLUMN 7a AS FOLLOWS:

1 = STREET → GO TO NEXT PERSON OR QUESTION 8
2 = PARKING LOT/GARAGE → CONTINUE WITH 7b
3 = NOT APPLICABLE → GO TO NEXT PERSON OR QUESTION 8
9 = DON'T KNOW → GO TO NEXT PERSON OR QUESTION 8

b. Is that facility enclosed?

CODE COLUMN 7b, AS FOLLOWS:

1 = YES → CONTINUE WITH QUESTION 7c
2 = NO → GO TO NEXT PERSON OR QUESTION 8
9 = DON'T KNOW → GO TO NEXT PERSON OR QUESTION 8

c. What kind of facility is it?

DESCRIBE BRIEFLY IN COLUMN 7c.

d. How many minutes does (NAME) spend in (FACILITY) each time (he/she) uses it?

ENTER IN COLUMN 7d.

HOUSEHOLD ROSTER AND ANSWER SPACE

QUESTIONS 1-7

	1	2	3	4	5	6	7			
H.M.N.	Com?	Mode(s)	Time	Miles	Trips	Time	a Park	b Encl.?	c Describe	d Time
01										
Name ______										
Age ______										
02										
Name ______										
Age ______										
03										
Name ______										
Age ______										
04										
Name ______										
Age ______										
05										
Name ______										
Age ______										
06										
Name ______										
Age ______										

8. The next few questions apply to the members of your household: (READ NAMES IN COLUMN 1.)

   a. Do any of these people work in an office building that contains or is located next to a parking garage?

      IF "NO" OR "DON'T KNOW," GO TO QUESTION 9.

      IF "YES," DETERMINE WHICH HOUSEHOLD MEMBER(S) AND ENTER HOUSEHOLD MEMBER NUMBER(S) IN COLUMN A OF THE TABLE BELOW. ASK 8b. AND 8c. FOR EACH PERSON WHOSE NUMBER IS ENTERED IN COLUMN A.

   b. Is the garage indoors, including underground, or is it outside?

      CODE COLUMN B OF THE TABLE AS FOLLOWS:

      1 = INDOORS
      2 = OUTDOORS
      9 = DON'T KNOW

   c. What is the approximate capacity of the garage? Would you say it is: 1 to 10 cars, 11 to 25 cars, 26 to 50 cars, greater than 50 cars?

      CODE COLUMN C OF THE TABLE AS FOLLOWS:

      1 = 1-10 CARS
      2 = 11-25 CARS
      3 = 26-50 CARS
      4 = GREATER THAN 50 CARS
      9 = DON'T KNOW

A	B	C
H.M.N.	Garage Location	Capacity of Garage

9. Do any of these people currently work full- or part-time in any of the following occupations?

READ LIST. FOR EACH "YES," ENTER THE HOUSEHOLD MEMBER NUMBER(S) ON THE LINE NEXT TO THE APPROPRIATE OCCUPATION. IF NO ONE IS EMPLOYED IN ANY OF THESE OCCUPATIONS, PLACE AN "X" ON THE LAST LINE BESIDE "NONE."

a. Service station attendant . . . . ______
b. Enclosed parking garage attendant . . . . ______
c. Taxi/bus/truck driver . . . . ______
d. Local delivery route man . . . . ______
e. Stevedore . . . . ______
f. Police officer . . . . ______
g. Fire fighter . . . . ______
h. Street or highway maintenance worker . . . . ______
i. Any occupation which requires continual travel . . . . . . ______

NONE ______

B.1 Thank you. That ends the telephone interview. As the next step, an interviewer will visit you to bring the monitor, an activity diary, and a questionnaire. At that time the interviewer will explain the use of these three items. Approximately 24 hours later, the interviewer will meet with you again to collect the study materials and provide you with another monitor for a second 24-hour period. The interviewer will return on the third day to collect the study materials and to pay the incentive.

On which of the following dates would it be most convenient for the interviewer to visit you the first time between 7 and 9 p.m.?

READ DATES FROM CONTROL CARD.

WAS A DATE CHOSEN?

☐ YES → ENTER DATE ON CONTROL CARD AND CONTINUE WITH B.2

☐ NO → GO TO B.5

B.2 What time between 7 and 9 o'clock in the evening would be convenient for the interviewer to visit you?

ENTER TIME ON CONTROL CARD AND CONTINUE WITH B.3.

B.3 a. Let me verify the address where the interviewer will meet you...

READ ADDRESS FROM CONTROL CARD IF MEETING AT HOME...
OBTAIN ADDRESS FROM RESPONDENT IF MEETING ELSEWHERE.

b. Are there any special instructions to finding that location?

ENTER ANY SPECIAL INSTRUCTIONS TO THE MEETING PLACE ON CONTROL CARD.

c. What is your full name?

ENTER FULL NAME ON CONTROL CARD AND CONTINUE WITH B.4.

B.4 We appreciate your contribution to this important study. Our interviewer will visit you on:

READ DATE AND TIME FROM CONTROL CARD.

Thank you again.

Goodbye.

B.5 Since you cannot participate on one of the pre-selected dates, we will not be able to use you further in this phase of the study. Thank you very much for your cooperation this far.

(IF RESPONDENT ASKS FOR DATES AGAIN, READ DATES FROM CONTROL CARD. IF RESPONDENT CHOOSES ONE OF THE DATES, ENTER IT ON THE CONTROL CARD.)

Goodbye.

DID RESPONDENT CHOOSE A DATE?

☐ YES → RETURN TO B.2

☐ NO → STOP.

RESULT CODES FOR COMPUTER MODEL INPUT QUESTIONNAIRE

PENDING CODES

ANSWERED

11 Appointment made
12 Call back, best time known
13 Call back, best time not known
14 Initial refusal or breakoff
15 First wrong connection
91 Other - specify

NOT ANSWERED

41 Ring, no answer
42 Regular busy signal
43 Phone problem
44 Answering machine (Message left)

FINAL CODES

01 Completed interview - visit arranged
02 Completed interview - no visit arranged
51 Final refusal or breakoff
52 Refusal or breakoff, not reached for conversion
53 Language barrier
54 Physically or mentally incompetent

71 Respondent no longer in HH
72 Number no longer in service (Oper.)
73 Final phone problem (Oper.)
74 Final no answer (6) (Super.)
75 Final busy (10) (Super.)
95 Other - specify

APPENDIX C

STUDY QUESTIONNAIRE

OMB No.: 2080-0003
Expires: September 1983

STUDY OF CARBON MONOXIDE EXPOSURE
DENVER, COLORADO

Sponsored by:

Environmental Monitoring Systems Laboratory
Environmental Protection Agency
Research Triangle Park, NC 27709

Conducted by:

PEDCo Environmental, Inc.
505 South Duke Street
Durham, North Carolina 27701

STUDY QUESTIONNAIRE

PEDCo ENVIRONMENTAL IS UNDERTAKING A RESEARCH STUDY FOR THE U.S. ENVIRONMENTAL PROTECTION AGENCY TO ASSESS MAN'S EXPOSURE TO CARBON MONOXIDE. THE INFORMATION RECORDED IN THIS QUESTIONNAIRE WILL BE HELD IN STRICT CONFIDENCE AND WILL BE USED SOLELY FOR RESEARCH INTO THE EFFECTS OF ENVIRONMENTAL FACTORS ON PUBLIC HEALTH. ALL RESULTS WILL BE SUMMARIZED FOR GROUPS OF PEOPLE: NO INFORMATION ABOUT INDIVIDUAL PERSONS WILL BE RELEASED WITHOUT THE CONSENT OF THE INDIVIDUAL. WHILE YOU ARE NOT REQUIRED TO RESPOND, YOUR COOPERATION IS NEEDED TO MAKE THE RESULTS OF THIS SURVEY COMPREHENSIVE, ACCURATE, AND TIMELY.

PID # ☐☐☐☐☐☐☐

INTRODUCTION

The questions in this questionnaire ask about your home, your commuting trips, your place of work, and your leisure activities. Your answers should reflect the events and circumstances of the 24-hour period you are using the monitor. Some questions may not apply to you; you are instructed in the questionnaire to skip those questions. Please read the questionnaire carefully and follow all instructions. To complete this questionnaire, you should circle a number or write in your answer. If you are unsure of an answer, please explain as fully as possible. If you have any questions about this questionnaire, the interviewer will be happy to assist you when he or she returns to collect this questionnaire, the monitor, and the Activity Diary.

The first set of questions deals with your home or living quarters.

1. Which of the following best describes your living quarters?

   CIRCLE ONE NUMBER.

   01 One-family house detached from other houses
   02 One-family house attached to one or more houses
   03 Duplex
   04 Apartment
   05 Mobile home or trailer
   06 Rented room
   07 Boat, van, etc.

2. Approximately how many square feet are in your living quarters?

   ______________ square feet

3. a. How many people live in your living quarters? (DO NOT INCLUDE YOURSELF.)

   ______________ people → IF "NONE," GO TO QUESTION 4.

   b. How many people who live with you smoke tobacco in any form?

   ______________ people → IF "NONE," GO TO QUESTION 4.

   c. How many people who live with you smoke cigarettes?

   ______________ people → IF "NONE," GO TO QUESTION 4.

   d. Approximately how many packs of cigarettes are smoked while you are at home during a normal week?

   CIRCLE ONE NUMBER.

   01 Less than 1 pack
   02 1-4 packs
   03 5-7 packs
   04 8 or more packs

4. Are the following items used in your living quarters, and if so, are they vented to the outside? If you do not have the item, circle 3.

CIRCLE ONE NUMBER ON EACH LINE.

		Yes, used and vented	Yes, used but not vented	Not Used
a.	Fireplace	1	2	3
b.	Wood stove	1	2	3
c.	Gas furnace	1	2	3
d.	Gas cooking stove	1	2	3
e.	Gas hot water heater	1	2	3
f.	Gas clothes dryer	1	2	3
g.	Gas or kerosene space heater	1	2	3
h.	Other gas appliance	1	2	3

↓

SPECIFY ______________________________

____

5. Are the following energy-saving devices present where you live?

CIRCLE ONE NUMBER ON EACH LINE.

		Yes	No	Don't Know
a.	Storm windows	1	2	3
b.	Storm door(s)	1	2	3
c.	Extra insulation	1	2	3
d.	Special dampers in stove or fireplace	1	2	3
e.	Other energy-saving device	1	2	3

↓

SPECIFY ______________________________

____

6. In your living quarters, do you use the following types of fans?

CIRCLE ONE NUMBER ON EACH LINE.

		Yes	No
a.	Attic fan	1	2
b.	Window fan	1	2
c.	Other type of fan	1	2

↓

SPECIFY ______________________________

____

7. What main type of heating system is used at your living quarters?
CIRCLE ONE NUMBER.

01 Steam or hot water system
02 Central warm air furnace with ducts to individual rooms, or central heat pump (forced air)
03 Built-in electric units, permanently installed in wall, ceiling, or baseboard
04 Floor, wall, or unvented furnace
05 Circulating, radiant, or room heaters, WITH flue or vent, burning gas, oil, or kerosene
06 Circulating radiant, or room heaters (not portable) WITHOUT flue or vent, burning gas, oil, or kerosene
07 Portable room heaters of any kind
08 Fireplace(s) or stove(s) burning coal, wood, or coke
09 Some other type
↓
SPECIFY: ______________________________
10 No heating equipment
94 Don't know

8. Do you use air conditioning in your living quarters?
CIRCLE ONE NUMBER.

01 Yes, a central air-conditioning system
02 Yes, window unit(s)
03 No

9. Is a garage attached to or within the structure in which you live?
CIRCLE ONE NUMBER.

01 Yes, used
02 Yes, not used
03 No

10. Are your living quarters located within three blocks of any of the following sites?

CIRCLE ONE NUMBER ON EACH LINE.

	Yes	No
a. Bus garage	1	2
b. Heavy vehicle maintenance area or depot	1	2
c. Site of open burning	1	2
d. Electricity or steam plant	1	2
e. Manufacturing plant with heavy smoke emission or power generator or furnaces	1	2

11. Do you travel to and from work, school, or any other place on a regular basis at least three times a week?

CIRCLE ONE NUMBER.

01 Yes → CONTINUE
02 No → GO TO QUESTION 20.

Questions 12-16 are about the trips you make on a regular basis during a normal week. If you travel to more than one place on a regular basis, answer for the trip that requires the longest time to complete.

12. a. Please list below in column A each mode of transportation (car, bus, subway, walk, etc.) you use in traveling to your destination. If you use more than one mode, list them in the order in which you use them.

b. For each travel mode you have listed in column A, enter in column B the total minutes you spend using this mode to travel to your destination.

c. In column C, circle "Yes" or "No" to indicate if smokers are present in each mode of transportation you have listed.

A	B	C
MODE OF TRANSPORTATION	TOTAL MINUTES SPENT TRAVELING TO DESTINATION	SMOKERS PRESENT?
		Yes No
		Yes No
		Yes No

13. Do you return home by the same mode(s) of transportation as those you listed in Question 12 above?

01 Yes → GO TO QUESTION 15.
02 No → CONTINUE.

14. a. Please list below in column A each mode of transportation (car, bus, subway, walk, etc.) you use in traveling from your destination. If you use more than one mode, list them in the order in which you use them.

b. For each travel mode you have listed in column A, enter in column B the total minutes you spend using this mode to travel from your destination.

c. In column C, circle "Yes" or "No" to indicate if smokers are present in each mode of transportation you have listed.

A	B	C
MODE OF TRANSPORTATION	TOTAL MINUTES SPENT TRAVELING FROM DESTINATION	SMOKERS PRESENT?
		Yes No
		Yes No
		Yes No

15. At what time do you arrive at your final destination?

Time Arrive: ____________ CIRCLE ONE. AM PM

16. At what time do you depart for home?

Time Depart: ____________ CIRCLE ONE. AM PM

17. About how many hours during an average week do you normally spend in a motor vehicle either as the driver and/or as a passenger? Include all time you spend commuting, shopping, on pleasure trips, etc.

Hours per week: ____________ → IF "NONE," GO TO QUESTION 20.

18. Please indicate the make, model, and year of the automobile in which you spend the most time in a normal week. If you do not use an automobile during a normal week, indicate below and skip to 20.

MAKE: ______________________________

MODEL: ______________________________

YEAR: ______________________________

☐ Do not use an automobile → GO TO QUESTION 20.

19. About how many hours during an average week do you spend in the motor vehicle described in Question 18?

Hours per week: __________

20. Do you work either full-time or part-time outside your home?

CIRCLE ONE NUMBER.

01 Yes → CONTINUE
02 No → GO TO QUESTION 32.

The next set of questions deals with the place at which you work.

21. Do you work at least part of the time in an enclosed area, other than in a motor vehicle?

CIRCLE ONE NUMBER.

01 Yes → CONTINUE.
02 No → GO TO QUESTION 28.

22. Which of the following best describes the enclosed area in which you work the majority of the time?

01 Office or other small area, work alone

02 Office or other small area shared with other people

03 Large area (factory floor, laboratory, store, etc.), work alone

04 Large area shared with other people

05 Circulate throughout building

06 Other (DESCRIBE) ______________________________

____

23. What is the approximate size of the enclosed area in which you work the majority of the time?

__________ feet by __________ feet

24. Is the enclosed area in which you work air-conditioned?

CIRCLE ONE NUMBER.

01 Yes, central air-conditioning system
02 Yes, window units(s)
03 No

25. Is a fan of any kind used in the enclosed area in which you work?

CIRCLE ONE NUMBER.

01 Yes, window fan
02 Yes, other kind of fan
03 Yes, both window and other fan
04 No

26. In the enclosed area in which you work the majority of the time, are you in the presence of smokers?

CIRCLE ONE NUMBER.

01 Yes, always (share work space with smoker(s))
02 Yes, most of the time
03 Yes, seldom
04 No

27. What main type of heating system is used at the place at which you work?

CIRCLE ONE NUMBER.

01 Steam or hot water system

02 Central warm air furnace with ducts to individual rooms, or central heat pump (forced air)

03 Built-in electric units, permanently installed in wall, ceiling, or baseboard

04 Floor, wall, or unvented furnace

05 Circulating, radiant, or room heaters, WITH flue or vent, burning gas, oil, or kerosene

06 Circulating radiant, or room heaters (not portable) WITHOUT flue or vent, burning gas, oil, or kerosene

07 Portable room heaters of any kind

08 Fireplace(s) or stove(s) burning coal, wood, or coke

09 Some other type
↓
SPECIFY: ______________________________

10 No heating equipment

94 Don't know

28. Do you work within three blocks of any of the following sites?
CIRCLE ONE NUMBER ON EACH LINE.

	Yes	No
a. Bus garage	1	2
b. Heavy vehicle maintenance area or depot	1	2
c. Site of open burning	1	2
d. Electricity or steam plant	1	2
e. Manufacturing plant with heavy smoke emission or power generator or furnaces	1	2

29. a. What kind of work do you do? (For example, typist, sales clerk, truck driver, etc.)

____

____

b. What kind of business or industry are you employed in? (For example, TV and radio manufacturing, retail shoe store, U.S. government, etc.)

____

____

30. How many hours do you normally work each week?

______________ hours a week

31. How many of the hours that you work each week (Question 30) do you spend working outdoors?

______________ hours a week

32. Please complete the table below concerning your leisure-time activities.

a. In column A, list up to five leisure-time activities at which you spend the most time in an average week; for example, hobbies, sports, shopping, at home activities, movies, concerts, etc.

b. In column B, describe the type of place where you participate in each of the activities you listed in column A.

c. In column C, enter the approximate amount of time you spend at each activity in an average week.

A ACTIVITY	B DESCRIPTION OF PLACE	C TIME SPENT
		________ hrs. ________ mins.
		________ hrs. ________ mins.
		________ hrs. ________ mins.
		________ hrs. ________ mins.
		________ hrs. ________ mins.

33. On shopping trips or any other leisure-time trips, do you park in an indoor parking garage, including parking decks?

CIRCLE ONE NUMBER.

01 Yes → CONTINUE
02 No → GO TO QUESTION 35.

34. Approximately how many total minutes do you spend in an indoor garage when you are on a leisure-time trip?

__________________ minutes

35. The last few questions are about you. Answers to these questions will be used only in the statistical interpretation of the data.

a. What is your sex?

CIRCLE ONE NUMBER.
01 Male
02 Female

b. How old were you on your last birthday?

Age: ______________

c. What is the highest level of education you completed?

CIRCLE ONLY ONE NUMBER.

01 Less than 8th grade
02 Some high school but did not graduate
03 High school graduate or equivalent
04 Some college but not a 4-year degree
05 4-year college degree
06 Post graduate work
07 Graduate degree

THANK YOU FOR YOUR COOPERATION. THE INTERVIEWER WILL COLLECT THIS QUESTIONNAIRE WHEN HE OR SHE RETURNS FOR THE MONITOR AND ACTIVITY DIARY.

FI USE ONLY

Type of Housing Structure:

A. Constructed of:

01 Frame
02 Masonry (brick, cinder block, stucco)
03 Combination
04 Other (DESCRIBE)

____

B. Structure is:

01 One story house/duplex
02 Two- or more-story house/duplex
03 Split level
04 Garden-type apartment/condominum
05 High rise apartment/condominum
06 Other (DESCRIBE)

____

FI No. ____________

Date ______________________

Comments ______________________________

APPENDIX D

INSTRUCTION MANUAL FOR PERSONAL EXPOSURE MONITOR

A.1 GENERAL

This manual provides general operation and maintenance instructions for the COED-1. The COED-1 is a customized instrument consisting of a General Electric (GE) Carbon Monoxide Detector, Model 15ECS3CO3, and a modified Magus DL-1 Data Logger. Since the Carbon Dioxide Detector has undergone only minor modification, the GE Operation and Maintenance Instructions are still effective.

A.2 DESCRIPTION OF GE CARBON MONOXIDE DETECTOR MODIFICATION

The battery pack with its associated hardware and the LCD Digital Display have been replaced.

The audio indicator and the LED warning lamp have been removed.

The flow indicator has been moved and fastened to the filter container.

The push button ON/OFF switch has been moved to the top of the analyzer (see Figure 1). The Magus DL-1 Data Logger incorporates numerous changes. The most important one is that only the Activity switch is accessible to the subjects and that all other functions will have to be carried out by technicians. Complete operator instructions are given in Sections A.5 and A.6.

A.3 GENERAL SPECIFICATIONS

Dimensions: 6.3 x 5.1 x 3.3 inches

Weight: 2.1 pounds (.95 kg)

Nominal Operating Time:

CO Detector: 24 hours

Data Logger: 3 days

(starting with fully charged batteries)

Battery Packs:

CO Detector: Four (4) Ni/Cd AA cells

Data Logger: Six (6) Ni/Cd AA cells

Battery Charger: Dual outputs via DIN connector.

Charging Time: 14 hours minimum

Battery Discharger (optional): Dual outputs via DIN connector

Discharging Time: 1 hour

Lower Detectable Limit: 1 ppm (LCD display reads to nearest whole number, 0 may be + or -).

Warm-up Time: 15 seconds (after 14 hour battery charge).

Response Time: Within 2 minutes to 90%

Attitude: Within 45° of vertical

Storage Temperature Range: (34 to 122°F) 1 to 50°C

A.4 DESCRIPTION OF THE COED-1

Figure 1 illustrates the instrument controls, LCD display and access points with the cover in place. The cover has been secured with two tamperproof screws. The unit consists of the CO detector and a data integrator. Its functional schematic is shown in Figure 2.

The control for the detector is located under the flexible black cover on the left side of the instrument. The ON/OFF pushbutton switch controls power from the battery pack to the pump and coulometer. Power is constantly applied to the sensor cell to maintain its stability regardless of the position of the ON/OFF switch.

The ambient air sample is drawn into the detector through the filter by an integral sample air pump. The sample is discharged to the CO sensor cell where the CO is oxidized, producing an electrical signal proportional to the CO level. The air sample is then exhausted through the flow indicator inside the case. The filter provides selectivity of the detector to CO by removing other interfering gases. Hydrogen, ethylene and acetylene are potential interferents and further filtration may be required.

The LCD will, under normal operating conditions, display the time.

The only data logger control accessible is the ACTIVITY switch. It is located on the left hand side under the flexible red cover.

Momentary depressing of the switch will tell the data logger to log the data. To assure the operator that the instrument has received the signal, the word GULP will be displayed.

All other controls are only accessible after the cover has been removed.

A.5 OPERATION OF THE CO DETECTOR

Since the CO detector is a G.E. Model 15ECS3CO3, the operating instructions given in its "Operation and Maintenance Instruction" manual are still valid. Therefore, except for locating the component mentioned in A.2, all instructions set forth by G.E. should be followed.

A.6 OPERATION OF THE DATA LOGGER

WARNING

Do not activate any switches until directed to do so.

A.6.1 INTRODUCTION

With the cover removed and the top switches facing the left, locate a small, white switch mounted on the metal surface to the left of the circuit board. This is the MODE switch. Above the MODE switch, on top of the unit, is a metal momentary contact switch. This is the ACTIVITY switch. On the bottom of the circuit board is a small switch, the ON/OFF power switch for the logger. To the left and slightly above it is the recorder output jack. Turning the unit 90° to the left (i.e., facing the top switches), in the input to the data logger can be seen plugged into the CO output jacket. Immediately below is the power pack (six [6] Ni/Cd batteries) for the logger. Fastened to the frame of the logger is a female DIN connector, pin #1 (negative)/pin #2 (positive).

WARNING: NEVER OPERATE UNIT WITHOUT BATTERY PACK IN PLACE

The data logger performs four basic functions:

1. Clock: keeps track of minutes, hours and days

2. Measure: measures, displays, and averages the data

3. Log: stores the averaged data and time for later recall

4. Display: recalls the stored data (time and average). The supplied units will not display the date.

A.6.2 DATA LOGGER MODES

The logger can be placed into one of nine different modes in the following sequence: cLr dAY hOUr nin LOG cLOc ALOG diSP

- cLr: clear the logger
- dAY: set the day
- hOUr: set the hour
- nin: set the minutes
- LOG: measure, display and log the data
- cLOc: display the time and log the data
- ALOG: turn the autolog feature on or off
- diSP: display the logged time and data
- Err: the logger enters the Err mode automatically when logging exceeds the memory capacity of the logging memory i.e., the user attempts to log more than 113 data points. The operator cannot

directly move the logger into the Err mode with MODE and ACTIVITY switches. If this occurs the data logger is defective.

A.6.3 OPERATION

1. Turn the power switch to the ON position. WARNING: IF THE POWER IS OFF, either by turning the data logger off or by dead batteries, THE DATA LOGGER WILL LOSE ALL OF ITS MEMORY.

2. Turn the MODE switch on (to the right). The LCD should display one of the previous mentioned modes. (If no mode is displayed, press momentarily the ACTIVITY switch. If "Err" is displayed, go to the "diSP" mode. Turn the MODE switch off to enter the mode. Then turn the MODE swtch back on.)

3. Press momentarily the ACTIVITY switch to advance to the next mode. Repeat until cLr is displayed.

NOTE

As long as the MODE switch is in the "ON" position the logger will display the current mode but will not actually enter it.

4. Turn the MODE switch off. This will enter the clear mode and the symbol ScLr will appear.

NOTE

This is a "soft clear". Its function is to start the clock and reset the display mode.

5. Press the ACTIVITY switch, the message "cLr" will appear. This [illegible] a

"hard" clear and ALL LOGGED DATA HAS BEEN ERASED. THIS FUNCTION SHOULD BE PERFORMED ONLY AT THE BEGINNING OF AN EXPERIMENT.

6. Turn MODE switch on!

7. Press the ACTIVITY switch.

8. Turn the MODE switch off!

9. Press the ACTIVITY switch repeatedly until the appropriate day is displayed.

10. Turn the MODE switch on!

11. Press the ACTIVITY switch

12. Turn the MODE switch off!

13. Press the ACTIVITY switch repeatedly, until the appropriate hOUr is displayed.

14. Turn the MODE switch on!

15. Press the ACTIVITY switch! The message min will appear.

16. Turn the MODE switch off! Press the ACTIVITY switch repeatedly until the appropriate minute is displayed.

17. Turn the MODE switch on!

SETTING THE CLOCK, DAY, HOUR OR MINUTES WIILL STOP THE CLOCK. IT HAS TO BE STARTED OR RESTARTED BY "HARD" OR "SOFT" CLEAR.

WARNING

A "HARD" CLEAR WILL DESTROY ALL STORED DATA.

A.6.4 METHOD RECOMMENDED FOR THE PERSONAL MONITOR STUDY

1. Press the ACTIVITY switch! The message LOG will appear.
2. Press the ACTIVITY switch! The message cLOc will appear.
3. Press the ACTIVITY switch! The message ALOG wiill appear.
4. Press the ACTIVITY switch! The message diSP will appear.
5. Press the ACTIVITY switch! The message cLr will appear.
6. Turn MODE switch off! The message ScLr will appear.
7. Turn the MODE switch on!
8. THE CLOCK IS RUNNING! THE CLOCK MODE DOES NOT ENABLE DATA LOGGING BEFORE ENTERING THE LOG MODE.

NOTE

This may be verified by repeatedly pressing the ACTION switch until the symbol cLOc appears.

9. Turn the MODE switch off! The time will be displayed.

10. Turn the MODE switch on!

11. Press the ACTIVITY switch repeatedly until LOG is displayed!

12. Turn the MODE switch off!

The data logger is now in the logging mode.

14. The LCD displays the current value of the input data.

NOTE

Pressing the ACTIVITY switch while in the LOG mode will cause the logger to log the current time and the arithmetic average of the data since the last logging or hard clear. When the ACTIVITY switch is activated, while in the LOG mode, the message GULP will be displayed when the sample is recorded. If the attempt to log the data exceeds the logger's memory capacity, the logger will enter its Err mode; the new data is ignored, but the old data is preserved.

15. Turn the MODE switch on!

16. Press the ACTIVITY switch!

17. The message cLOc will appear.

18. Turn the MODE switch off!

19. Press the ACTIVITY switch

20. Data is being logged.

21. The clock mode does not enable data logging, as long as the LOG mode has been entered after a "hard" clear.

22. Pressing the ACTIVITY switch while in the cLOc mode will cause the logger to log the current time and arithmetic average of the data since the last logging.

23. Turn the MODE switch on!

24. Press the ACTIVITY switch!

25. The messge ALOG will appear.

26. Turn the MODE switch off!

27. The logger is now in the "autolog" mode.

NOTE

The "autolog mode displays the state of the autolog feature and allows the user to change the state by pressing the ACTIVITY switch. When autologging is enable, a YES is displayed. When autologging is on (YES), the data logger will log data when the ACTIVITY switch is pushed or automatically every hour on the hour. When autolog is off (NO), data is logged only when the ACTIVITY switch is depressed while in the LOG or cLOc mode. A "hard" clear of the data logger turns off the autolog feature.

28. Turn the MODE switch on!

29. Press the ACTIVITY switch! The message diSP will appear.

30. Turn the MODE switch off!

31. The logger is now in the "DISPLAY" mode.

NOTE

The "display" mode allows the user to examine the data that have been previously logged. Each logged data point is presented as two displays. The time (hours and minutes) is presented first, and then the average of the data. The average is presented as three digits to the left of the decimal point and one to the right. THE USER GOES TO THE NEXT DISPLAY BY MOMENTARILY PRESSING THE ACTIVITY SWITCH. When finished with one logged data point (2 displays), the next is represented. WHEN NO MORE DATA ARE AVAILABLE, THE LOGGER DISPLAYS A "dOnE" message.

DISPLAYING THE DATA DOES NOT ERASE IT.

The logged data stays in the logger until the "hard clear" or the logger is turned off (by the ON/OFF switch as the batteries run low). A "soft clear" will rest the display mode and allow the user to redisplay the old data as well as any new data. If the display has reached the "dOnE" message, the next entry to the display will show the "dOnE" unless a "soft clear" has been performed.

APPENDIX E

SELECTED PAGES FROM ACTIVITY DIARY

OMB No.: 2080-0003
Expires: September 1983

STUDY OF CARBON MONOXIDE EXPOSURE
DENVER, COLORADO

ACTIVITY DIARY

PID # ____________________

CO Monitor # _____________

Monitoring Period:

Begin: Date ____/____/____ Time: ☐☐☐☐

End: Date ____/____/____ Time: ☐☐☐☐

In completing this diary, please follow the instructions on the next two pages. Refer to the instructions and examples as needed.

Use as many pages of this diary as necessary to record information about all of your activities for the 24 hours you are using the monitor.

If you have questions or problems during the 24 hours, call the interviewer:

Name ______________________________

Telephone Number ______________________

If you cannot reach the interviewer, call:

Mitch Veeder
Colorado Market Research
Denver, Colorado 80222

Weekdays 8:30 a.m. - 5:00 p.m.: (303) 759-9494

David Dunbar
PEDCo Environmental, Inc.

Nights and weekends: COLLECT (919) 782-8692

INSTRUCTIONS FOR COMPLETING THE ACTIVITY DIARY

The Activity Diary is intended to provide certain information about the various activities in which people participate in a typical 24-hour period. Data recorded on the diary, together with data measured by the air monitor, will be used to describe the level of exposure to carbon monoxide for people in this area. In order that these data be as complete and accurate as possible, please follow these instructions carefully.

1. Each time you change activities, complete one page of the diary. Push the "Activity" button on your monitor and enter the current time, as displayed on the monitor, in the four boxes at the top of the left column.

2. When you have pushed the "Activity" button and recorded the time, briefly describe, in Part A, the activity you are beginning. Examples of suitable entries for Part A include "cooking breakfast," "waiting for bus," "driving to grocery store," "working at desk," "visiting friends in their livingroom," and "sleeping in bedroom." Next complete Parts B through F, as applicable. If you are asked to "SPECIFY," please be as specific as possible. Parts C and D are mutually exclusive, and either requires an exact address. If the exact address is unknown, please enter the nearest intersection. Part E is to be completed only if you are indoors. Parts B and F must be completed everytime. Use as many pages as necessary to record information about all of your activities during the 24 hour monitoring period.

3. If you are in transit and use more than one mode of transportation, complete a separate page for each mode. If any other activity causes you to move to a location with different characteristics (for example, going from an indoor to an outdoor location at work), complete a separate page for each location.

4. You need not fill out a page in the diary when starting an activity which you expect to last less than 5 minutes. As a single exception, always push the "Activity" button and complete a page in the diary when entering an enclosed garage or parking structure.

5. When you retire, push the button, complete a page of the diary, and place the monitor beside your bed. The monitor will automatically store data every hour. When you get up, push the button and complete the next page of the diary.

6. If your activities take you into an area or create a situation that is dangerous to the monitor or hazardous to you because of the monitor, record the time and describe the situation in Part A. Place the monitor in a safe place as near as possible to you and retrieve the monitor as soon as possible; record the time and your new activity.

7. If there is any problem with the monitor, note the time and record the problem in Part A. Any other unusual circumstances, activities, or exposures should also be noted in Part A. Be as specific as possible.

8. The interviewer will return after approximately 24 hours to retrieve the monitor and collect the Activity Diary. The interviewer will make a final entry at that time. Six examples of properly completed Activity Diary pages follow.

TIME FROM MONITOR | 1 | 8 | 4 | 1 |

A. ACTIVITY

cooking dinner

EXAMPLE

B. LOCATION

In transit 1

Indoors, residence . . . . . . [✓ 2]

Indoors, office 3

Indoors, store 4

Indoors, restaurant 5

Other indoor location 6

Specify: ____________

Outdoors, within 10 yards of road or street 7

Other outdoor location 8

Specify: ____________

Uncertain 9

C. ADDRESS (if not in transit)

456 South Gilpin St.

D. ONLY IF IN TRANSIT

(1) Start address ____________

(2) End address ____________

(3) Mode of travel:

Walking 1

Car 2

Bus 3

Truck 4

Train/subway 5

Other 6

Specify: ____________

E. ONLY IF INDOORS

(1) Garage attached to building?

Yes . . . . [✓ 1]

No 2

Uncertain 3

(2) Gas stove in use?

Yes . . . . [✓ 1]

No 2

Uncertain 3

F. ALL LOCATIONS

Smokers present?

Yes 1

No . . . . [✓ 2]

Uncertain 3

TIME FROM MONITOR | 0 | 8 | 0 | 1 |

A. ACTIVITY

working in machine
shop

EXAMPLE

B. LOCATION

In transit 1
Indoors, residence 2
Indoors, office 3
Indoors, store 4
Indoors, restaurant 5
Other indoor location . . . . . [✓ 6]
  Specify: factory
Outdoors, within 10 yards of road or street 7
Other outdoor location 8
  Specify: ______
Uncertain 9

C. ADDRESS (if not in transit)

Acme Electric
near corner of Oak St.
and Pine Avenue

D. ONLY IF IN TRANSIT

(1) Start address ______

(2) End address ______

(3) Mode of travel:

Walking 1
Car 2
Bus 3
Truck 4
Train/subway 5
Other 6
  Specify: ______

E. ONLY IF INDOORS

(1) Garage attached to building?

Yes 1
No . . . . [✓ 2]
Uncertain 3

(2) Gas stove in use?

Yes 1
No . . . . [✓ 2]
Uncertain 3

F. ALL LOCATIONS

Smokers present?

Yes . . . . [✓ 1]
No 2
Uncertain 3

TIME FROM MONITOR 0833

A. ACTIVITY

walking through
parking garage

EXAMPLE

B. LOCATION

In transit 1
Indoors, residence 2
Indoors, office 3
Indoors, store 4
Indoors, restaurant 5
Other indoor location 6
Specify: ____________________

Outdoors, within 10 yards of road or street 7
[✓ Other outdoor location . . . . 8]
Specify: parking garage

Uncertain 9

C. ADDRESS (if not in transit)

200 Arapahoe St.

D. ONLY IF IN TRANSIT

(1) Start address ____________________

(2) End address ____________________

(3) Mode of travel:

Walking 1
Car 2
Bus 3
Truck 4
Train/subway 5
Other 6
Specify: ____________________

E. ONLY IF INDOORS

(1) Garage attached to building?

Yes 1
No 2
Uncertain 3

(2) Gas stove in use?

Yes 1
No 2
Uncertain 3

F. ALL LOCATIONS

Smokers present?

Yes 1
[✓ No . . . . 2]
Uncertain 3

TIME FROM MONITOR 1735

A. ACTIVITY

walking dog

EXAMPLE

B. LOCATION

In transit 1

Indoors, residence 2

Indoors, office 3

Indoors, store 4

Indoors, restaurant 5

Other indoor location 6

Specify: ______

[✓ Outdoors, within 10 yards of road or street . . . . 7]

Other outdoor location 8

Specify: ______

Uncertain 9

C. ADDRESS (if not in transit)

123 East Iowa Ave.

D. ONLY IF IN TRANSIT

(1) Start address ______

(2) End address ______

(3) Mode of travel:

Walking 1

Car 2

Bus 3

Truck 4

Train/subway 5

Other 6

Specify: ______

E. ONLY IF INDOORS

(1) Garage attached to building?

Yes 1

No 2

Uncertain 3

(2) Gas stove in use?

Yes 1

No 2

Uncertain 3

F. ALL LOCATIONS

Smokers present?

Yes 1

[✓ No . . . . 2]

Uncertain 3

TIME FROM MONITOR 1723

A. ACTIVITY

driving from office
to grocery store

EXAMPLE

B. LOCATION

In transit	[✓ 1]
Indoors, residence	2
Indoors, office	3
Indoors, store	4
Indoors, restaurant	5
Other indoor location	6
Specify:	
Outdoors, within 10 yards of road or street	7
Other outdoor location	8
Specify:	
Uncertain	9

C. ADDRESS (if not in transit)

D. ONLY IF IN TRANSIT

(1) Start address
200 Arapahoe St.

(2) End address
101 Ellsworth Ave.

(3) Mode of travel:

Walking	1
Car	[✓ 2]
Bus	3
Truck	4
Train/subway	5
Other	6
Specify:	

E. ONLY IF INDOORS

(1) Garage attached to building?

Yes	1
No	2
Uncertain	3

(2) Gas stove in use?

Yes	1
No	2
Uncertain	3

F. ALL LOCATIONS

Smokers present?

Yes	1
No	[✓ 2]
Uncertain	3

TIME FROM MONITOR 0747

A. ACTIVITY

walking from home to bus stop

EXAMPLE

B. LOCATION

In transit . . . . [✓ 1]
Indoors, residence 2
Indoors, office 3
Indoors, store 4
Indoors, restaurant 5
Other indoor location 6
Specify: ____________
Outdoors, within 10 yards of road or street 7
Other outdoor location 8
Specify: ____________
Uncertain 9

C. ADDRESS (if not in transit)

____

D. ONLY IF IN TRANSIT

(1) Start address Apt. 101
789 Pierce St.

(2) End address corner of
W. 32nd Ave. & Marshall St.

(3) Mode of travel:

Walking . . . . [✓ 1]
Car 2
Bus 3
Truck 4
Train/subway 5
Other 6
Specify: ____________

E. ONLY IF INDOORS

(1) Garage attached to building?

Yes 1
No 2
Uncertain 3

(2) Gas stove in use?

Yes 1
No 2
Uncertain 3

F. ALL LOCATIONS

Smokers present?

Yes 1
No . . . . [✓ 2]
Uncertain 3

TIME FROM MONITOR ☐☐☐☐

A. ACTIVITY

____

____

____

____

B. LOCATION

In transit	1
Indoors, residence	2
Indoors, office	3
Indoors, store	4
Indoors, restaurant	5
Other indoor location	6
Specify: ____________________	
Outdoors, within 10 yards of road or street	7
Other outdoor location	8
Specify: ____________________	
Uncertain	9

C. ADDRESS (if not in transit)

____

____

____

D. ONLY IF IN TRANSIT

(1) Start address ____________________

____

(2) End address ____________________

____

(3) Mode of travel:

Walking	1
Car	2
Bus	3
Truck	4
Train/subway	5
Other	6

Specify: ____________________

____

E. ONLY IF INDOORS

(1) Garage attached to building?

Yes	1
No	2
Uncertain	3

(2) Gas stove in use?

Yes	1
No	2
Uncertain	3

F. ALL LOCATIONS

Smokers present?

Yes	1
No	2
Uncertain	3

APPENDIX F

FIELD DATA SHEET

CO EXPOSURE STUDY, DENVER, COLORADO
FIELD DATA SHEET[a]

Monitor ID: ☐☐☐☐☐☐

Status Sheet No. ☐☐☐

PID #: ☐☐☐☐☐☐☐

Read by: ☐☐☐☐☐☐

Verified by: ☐☐☐☐☐☐

Approved by: ☐☐☐☐☐☐

Completed: ☐

	Month	Day	Year
Date Sampled:	☐☐	☐☐	☐☐
Date Read:	☐☐	☐☐	☐☐
Date Verified:	☐☐	☐☐	☐☐
Date Approved:	☐☐	☐☐	☐☐

Loaded: ☐

Seq. No.	Time[b]	CO conc. (ppm)	Activity diary data								
			A	B	C	D1	D2	D3	E1	E2	F
01	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐
02	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐
03	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐
04	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐
05	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐
06	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐
07	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐
08	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐

NOTE: a - Use back of form to describe any problems.
b - Record all times in 24-h clock.

Seq. No.	Time[b]	CO conc. (ppm)	Activity diary data								
			A	B	C	D1	D2	D3	E1	E2	F
09	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐
10	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐
11	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐
12	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐
13	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐
14	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐
15	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐
16	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐
17	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐
18	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐
19	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐
20	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐
21	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐
22	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐
23	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐
24	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐
25	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐
26	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐
27	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐
28	☐☐☐☐	☐☐☐ . ☐	☐☐	☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐	☐☐

Seq. No.	Time^{b}	CO conc. (ppm)	Activity diary data								
			A	B	C	D1	D2	D3	E1	E2	F
29	□□□□	□□□ . □	□□	□□	□□□□□	□□□□□	□□□□□	□□	□□	□□	□□
30	□□□□	□□□ . □	□□	□□	□□□□□	□□□□□	□□□□□	□□	□□	□□	□□
31	□□□□	□□□ . □	□□	□□	□□□□□	□□□□□	□□□□□	□□	□□	□□	□□
32	□□□□	□□□ . □	□□	□□	□□□□□	□□□□□	□□□□□	□□	□□	□□	□□
33	□□□□	□□□ . □	□□	□□	□□□□□	□□□□□	□□□□□	□□	□□	□□	□□
34	□□□□	□□□ . □	□□	□□	□□□□□	□□□□□	□□□□□	□□	□□	□□	□□
35	□□□□	□□□ . □	□□	□□	□□□□□	□□□□□	□□□□□	□□	□□	□□	□□
36	□□□□	□□□ . □	□□	□□	□□□□□	□□□□□	□□□□□	□□	□□	□□	□□
37	□□□□	□□□ . □	□□	□□	□□□□□	□□□□□	□□□□□	□□	□□	□□	□□
38	□□□□	□□□ . □	□□	□□	□□□□□	□□□□□	□□□□□	□□	□□	□□	□□
39	□□□□	□□□ . □	□□	□□	□□□□□	□□□□□	□□□□□	□□	□□	□□	□□
40	□□□□	□□□ . □	□□	□□	□□□□□	□□□□□	□□□□□	□□	□□	□□	□□
41	□□□□	□□□ . □	□□	□□	□□□□□	□□□□□	□□□□□	□□	□□	□□	□□
42	□□□□	□□□ . □	□□	□□	□□□□□	□□□□□	□□□□□	□□	□□	□□	□□
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Seq. No.	Time^b	CO conc. (ppm)	Activity diary data A	B	C	D1	D2	D3	E1	E2	F
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APPENDIX G

SITE DESCRIPTIONS OF FIXED-SITE MONITORS[1]

Permanent Stations

Highlands (060080002F01): 8100 South University Blvd.

The Highlands air monitoring station is located 12½ miles south-southeast of the downtown central business district (CBD), at the corner of County Line Rd. and University Blvd. The station itself is set back from both highways by a distance of over 500 feet and is at the top of a rolling hill. The area surrounding the station is fenced, with the only traffic being general maintenance personnel within the Water Department grounds. Terrain is generally rolling hilled areas with the station elevation being 5700 feet above mean sea level (MSL). Within one mile of the station in all directions are residential housing areas. This site is the highest monitoring station in Denver and because of the elevation and location on top of a hill, it continually receives good ventilation and generally low pollution readings.

Aurora (060140002F01): 50 South Peoria

The Aurora monitoring station is located 8 miles east-southeast of the Denver CBD. The station is on the edge of a low usage parking lot at the Aurora Municipal Golf Course. The nearest residential area is 1/4 mile northeast of the station with no commercial or industrial facilities in the vicinity. Station elevation is 5435 feet MSL. Generally, the topography is flat in all directions with no obstructing buildings within any reasonable distance. During the winter season the parking lot is not generally used, as the golf course is not in operation giving this site a true neighborhood concentration picture.

CAMP (060580002F01): 2105 Broadway

The Continuous Air Monitoring Project (CAMP) station is the oldest monitoring station in the Denver area. It is located in the central downtown region in flat terrain at an altitude of 5220 feet MSL. This station is under a center-city commercial designation exhibiting the major qualities of a heavy traffic oriented site. Major traffic intersections and arteries exist within a few hundred meters in all directions. Carbon monoxide values are significantly affected by local traffic. The station location and traffic orientation is generally representative of the large downtown CBD with poor ventilation and high density traffic. To the east of the station some residential housing starts. In the other directions, one to three story buildings are present within one half block. The station itself is located on a triangular piece of park land at the three-way intersection of Broadway, Champa, and 21st Sts.

National Jewish Hospital East (060580013F01): 14th and Albion

The National Jewish Hospital (NJH) East site is a new location for the now discontinued NJH site operated in Denver since 1973. The previous location suffered from poor ventilation due to the probe being located out the second story window in the middle of the building on the west side of Colorado Blvd. The new location is on the edge of a low influx parking lot (i.e., filled and emptied once/day) surrounded by the generally open space in all directions for at least 100 feet. The station is three miles east of the downtown CBD at an elevation of 5300 feet MSL. To the west, one of Denver's major arteries, Colorado Blvd., is located at a distance of 200 feet from the station. Less major streets are within 100 feet to the south and 600 feet to the north. This station would fall into the worst-case neighborhood classifications and generally reflects levels influenced by the high density traffic on Colorado Blvd. and Colfax Ave. to the north. Generally flat terrain exists with a three story building being located 100 feet to the north. The area is primarily residential with no commercial sources in the vicinity.

Carriage (060580014F01): 2325 Irving

The Carriage site derives its name from the location in the middle of a city block (i.e., along the alley at mid-block) on a plot of ground owned by Denver and known as a "carriage lot." This site is at an elevation of 5300 feet MSL and is 2½ miles west of the downtown CBD. The terrain is relatively flat and residential housing surrounds the site at distances of approximately 75 to 100 feet. The site is isolated enough that it is unaffected by localized traffic patterns. Topographically, the site is located along a ridge out of the Platte River Valley that cuts through the CBD area. However, it is only 80-100 feet above the valley floor and well within the influence of major traffic influx into and out of the CBD.

Arvada (060120002F01): 5701 Garrison

The Arvada station is classified as a suburban residential site. This station is located about 6 miles northwest of the central downtown area at an elevation of 5385 feet MSL. This site is considered to be in relatively rugged terrain compared to the other monitoring stations. The surrounding hills could influence local pollutant values to a certain degree, depending upon existing meteorological conditions. The source environment of both the near and far (up to 2 miles) vicinity shows no major industrial sources that would significantly affect carbon monoxide. A number of indirect sources do exist less than one mile from the station which appear to periodically influence the carbon monoxide levels. These indirect sources are (1) major traffic intersections and (2) large shopping centers.

Temporary Stations

Oakland (062080817F05): 4845 Oakland

The Oakland air monitoring station was located approximately 8 miles east-northeast of the Denver CBD in Montbello, Colorado. This location is about 1½ miles northeast of Stapleton International Airport. The CO monitor was placed in the southwest corner of the Oakland Street Elementary School. The school is located on the eastern bounds of a large commercial area north of Route I-70 and west of Peoria Sts. Terrain is relatively flat with ground elevations not varying more than +/- 40 feet within a one mile radius. Station elevation was 5303 feet MSL. To the north about one-half mile away lies open fields and less than one-half mile to the east lies a large residential community. On the south side commercial buildings are present with I-70 about 1½ miles away. In the immediate vicinity of the school are commercial buildings in all directions; however, the probe is well ventilated in all directions with the closest building 55 feet to the west.

Wyatt (062080818F05): 3620 Franklin Street

The Wyatt air monitoring station is located less than one-half mile northeast of the Denver CBD. This location is one mile south of Route I-70, and 1½ miles west of Colorado Blvd. The monitor was installed on the north side, third floor, of the Wyatt School. School property is bounded by Franklin and Gilpin Streets and by 36th and 37th Avenues. A residential community surrounds the school on all sides; however, the CBD is present on the west and southwest. In the immediate vicinity no buildings pose an obstruction to the probe siting except the Wyatt school building itself. To the north, a portion of the school extends to the same height as the inlet probe. On the east, houses lie on the east side of Gilpin Street. To the south the probe is partially shielded by a portion of the school which extends 15-20 feet higher than the inlet probe. The inlet probe is unobstructed for 270 degrees with open exposure to the west. Terrain is relatively flat with ground elevations varying +/- 60 feet within a one mile radius. Station elevation is 5208 feet MSL.

Metro (062080819F05): Speer Blvd. and Lawrence Street

The Metro air monitoring station is within the Denver CBD on the southeast side. The station was located on the third floor of the chemistry building at Metropolitan State College. This location is 214 feet west of Speer Blvd. and 298 feet southeast of Lawrence Street. Route I-25 is approximately 1½ miles to the west of the site. The building is bounded to the southwest and to the northeast by two other small cross streets. To the north, west, and south the building is surrounded by the Auraria Campus. On the east side is the commercial downtown community with stores and office buildings. Ground elevations vary +/- 40 feet within a one mile radius. Station elevation is 5203 feet MSL. The closest building higher than the inlet probe is a church located 304 feet to the south. Roof structures on the chemistry building may produce air turbulence but should not restrict air flow.

Bryant-Webster (062080820F05): 3635 Quivas Street

The Bryant-Webster air monitoring station is located 1½ miles northeast of the Denver CBD. This location is just less than one mile northwest of Route I-25 and ¼ mile south of 38th Avenue. The monitor was located on the third floor east face of the Bryant-Webster school. The school is bounded by Quivas and Shoshone Streets and by 36th and 37th Avenues. Approximately 1½ miles to the west and to the southwest lie Federal and Speer Blvd., respectively. The school is surrounded by a residential community. Large trees line Quivas Street on the eastern exposure. The terrain slopes to lower elevations at a significant gradient toward downtown. Ground elevations vary +/- 90 feet within a one mile radius. Station elevation is 5270 feet MSL. In the immediate vicinity houses line the eastern side of Quivas. The inlet probe is shielded on the west by the school extending 50 feet above the probe. Ventilation is still good with unrestricted air flow 270 degrees.

Sherman (0602080821F05): 208 Grant Street

The Sherman air monitoring station is located 2½ miles south of the Denver CBD. This location is about one-half mile southwest of Speer Blvd. and east of Broadway and Lincoln Streets. The monitor was installed on the third floor east face of the Sherman School. The school is located on the northeast corner of Grant Street and 2nd Avenue. The area surrounding the school is residential with the nearest houses 100 feet to the east. A commercial area lies 3/4 miles to the southwest. The terrain slopes to the northwest with ground elevations varying +/- 40 feet within a one mile radius. Station elevation is 5272 feet MSL. In the immediate vicinity of the inlet probe the nearest obstruction is a building 47 feet to the north. This building extends approximately 15 feet to the east beyond the probe. The school building itself shields the probe from the west. To the west on the far side of the building lies an open field. Air flow is unrestricted for 270 degrees.

Denison (062080822F05): 1821 South Yates Street

The Denison air monitoring station is located approximately six miles southwest of the Denver CBD. The station is located just east of Sheridan Blvd., and north of Jewell Avenue in the Denison Elementary School. The monitor was installed on the third floor of the school with the probe extending above the roof. The school is situated on the southwest corner of Colorado Avenue and Yates Street. To the north, east, and south lies a residential community. On the west side, west of Sheridan, lies a large commercial area. Southwest of the monitoring location are several shopping malls. The terrain is made up of gently rolling hills with ground elevations varying +/- 80 feet within a one mile radius of the site. The school is located in a low level air drainage field called Sanderson Gulch with the Clairfield Reservoir to the west. Station elevation is 5420 feet MSL. Houses surround the school except on the west side where a commercial building lies 450 feet away. No buildings pose an obstruction in the immediate vicinity.

Pitts (062080823F05): 3509 South Glencoe

The Pitts air monitoring station is located approximately nine miles south-southeast of the Denver CBD. It is located one-half mile to the west of Route I-25 and a 147 feet south of Hampden Avenue. The monitoring station is located on the third floor of the Pitts Elementary School. The school lies within a residential community with houses immediately to the east and south and across Hampden Avenue to the north. On the west is a small shopping center. Within a one-mile radius lie many commercial communities, such as to the southwest and to the east across Route I-25. Gently rolling terrain surrounds the school with the ground sloping to higher elevations to the south and lower elevations to the north and west. Ground elevations vary +/- 80 feet within a one mile radius from the site. Station elevation is 5534 feet MSL. The station has good ventilation characteristics with no obstructions in the immediate vicinity.

Miller (062080824F05): 3600 South Elati Street

The Miller air monitoring station is located approximately seven miles due south of the Denver CBD. It is located one half mile east of Santa Fe Drive and 500 feet south of Hampden Avenue. The monitor is located on the first floor of the Miller Building which is being used as an arts and crafts center. The probe extends above the roof of the single story building on the east side. Broadway Blvd. lies one half mile to the east. Property bounds at site are between Ithica and Jefferson Avenues on the north and south, and between Elati and Delaware Streets on the west and east. Within 500 feet from the site, open fields and a residential community are present; however, to the north and west lies substantial commercial communities. Cinderella City is located 1/4 mile north-northwest of the site. Site terrain is extremely variable with several rises in terrain but generally ground elevations slopes to lower elevations towards the Platte River to the northwest. Elevation changes are approximately +/- 70 feet within a one mile radius of the site. Station elevation is 5318 feet MSL. In the immediate vicinity the ventilation is excellent as no buildings pose an obstruction.

Greenwood (062080825F05): 6060 South Quebec Street

The Greenwood air monitoring station is located approximately 12 miles south-southeast of the Denver CBD. It is located in a rural setting ½ mile west of Route I-25 and 1056 feet south of Orchard Road. The monitor is situated in a Colorado Highway Department air monitoring trailer in Greenwood Village. The trailer is installed next to the Highway Department and Greenwood Village Municipal buildings. The immediate property surrounding the trailer is bounded by Quebec and Syracuse Streets on the east and west and by Orchard Road and Maplewood Place on the north and south. In all directions, open fields are present with a few commercial and public buildings. The widely scattered trees pose no obstruction to station ventilation. A low usage gravel parking lot exists immediately to the south of the trailer. The terrain is made up of rolling hills with ground elevations varying +/- 120 feet within one mile of the station. The station elevation is 5620 feet MSL. Ground slopes towards lower elevations to the north and northwest. Little Dry Creek and an unnamed gulch lie to the west and northwest of the station. The general area is subjected to high density, slow moving traffic during the rush hour periods but moderate levels in off peak periods.

Reference

1. The Denver Carbon Monoxide Study: Fixed Station Siting, Data Acquisition, and Quality Assurance. Air Pollution Control Division, Department of Health, State of Colorado. September 1983.

APPENDIX H

SPECIAL FIELD SCREENING ACTIVITIES, ASSOCIATED CONTROL CARDS, AND WORK SHEETS

November 10, 1982
Revision 2

Special Field Screening Activities

Two special portions of the population exist which were not screened during the initial telephone household screening phase of the study. These two portions include: 1) those housing units without phones, with unlisted numbers, or whose phones were temporarily out-of-service during the screening, and 2) those housing units not included in the Donnelley listing used to create the screening sample. In order to allow all of the population of interest to have a chance to be selected for the main phase of the study, a special attempt to screen a sample of the two portions must be made. Using the instructions which follow, an attempt will be made to administer the Field Version of the Household Screening Questionnaire to each of the identified housing units. If no eligible person (a 16 year old or older resident of the house, who is physically and mentally capable of responding) is at the home, the correct phone number for the residence should be obtained and recorded. These cases will be screened by telephone from the Central Office.

A. Cases Without Previous Telephone Contact

After completion of the telephone screening phase, all the cases where no telephone contact was made were identified and a sample of these cases selected. A list of these cases has been generated and the appropriate information entered in Section A (Assignment Information) of the yellow control card labeled "No Previous Telephone Contact." This information should also be entered on the right hand corner of the Household Screening Questionnaire - Field Version. Given this information the field interviewer must find the housing unit and, if an eligible respondent is available, complete a field screener. If no eligible respondent is available, obtain a telephone number and record it on the yellow control card in the space next to the words "new phone #." In some cases, an old phone # is provided. Check to be sure that the new number is not the same as the old number, since the old number has already been used and is not correct for this housing unit. If there is no one at home, try to obtain the telephone number from a neighbor or by using a local phone book. Using the resident's name--as found on a mailbox--and the correct address, a correct phone number may be obtained.

Keep a record of your efforts on this activity by completing the blue work sheet (labeled "Cases with No Previous Telephone Contact") as follows:

1. When you receive your assignment, enter the assignment information from the yellow control card on each screener you receive.
2. Put your name and FI ID # on the top of each blue sheet.
3. As you work on each of your assigned cases, complete the screener as indicated, and then enter the date and the correct new phone number on the appropriate lines of the blue work sheet and the yellow control card.
4. If you have completed an entire interview at the housing unit, put a check in the box in the right-hand column of the blue work sheet and mark yes under successful screen on the yellow control card. A complete interview is one where no additional information can be obtained by any further efforts, either in person or by phone.

Complete your work on each case by assigning a Field Result Code from the list in Figure 1. Place the code in the top center of the first page of the screener and enclose it in a circle; also place this code and your FI ID # in Section C of the yellow control card under the columns marked result code and FI ID.

B. Missed Housing Units

1. For each listing to be checked for Missed Housing Units, a gold work sheet has been prepared. The information identifying the starting point for missed housing units should be entered in Section A (upper left-hand corner). This form is to be used to record and document your efforts regarding the missed housing units.
2. Identify the housing unit corresponding to the address shown in Section A. In some cases, the street address on the label will not be sufficient by itself to uniquely identify a specific housing unit. Many times the address is simply the address of an apartment complex, trailer park, or other multiple-residence establishment. The address can even be a street or road name with no house number, but this occurs mainly in rural areas. Whenever the address in Section A corresponds to more than one housing unit, the name in Section A is to be used to identify a particular housing unit.

01 - Completed Interview/Telephone Number Obtained
02 - Completed Interview/Telephone Number Not Obtained
03 - Completed Interview/No Telephone Available
05 - Entire Household Moving

11 - No Age Eligible/Telephone Number Obtained
12 - No Age Eligible/Telephone Number Not Obtained
13 - No Household Resident/Telephone Number Obtained
14 - No Household Resident/Telephone Number Not Obtained
15 - No Competent Resident/Telephone Number Obtained
16 - No Competent Resident/Telephone Number Not Obtained
17 - Language Barrier/Telephone Number Obtained
18 - Language Barrier/Telephone Number Not Obtained

20 - Refusal/Breakoff
25 - No Contact

30 - Not a Residence
31 - Vacant
32 - Demolished/Condemned
33 - No Such Address

40 - Other, (Specify) ________________________________

Figure 1. Field result codes - for household screening.

Consider, for example, an address which identifies an entire apartment complex, rather than a specific apartment. Suppose that the name shown in Section A is Jack Jackson. The housing unit corresponding to the address is then defined to be the apartment in which Jack Jackson either currently resides or previously resided, assuming that he did reside at the apartment complex at some time. If the apartment manager or other supervisor of the establishment cannot identify a unit either presently or formerly occupied by Jack Jackson, the address is to be regarded as invalid, i.e., not corresponding to any housing unit. If you are unable to find a single housing unit in Section A corresponding to the address in Section A, stop work on the case and document your attempts at finding a housing unit corresponding to the address in Section A. Otherwise, if you are able to identify a particular housing unit that corresponds to the address in Section A, determine if the housing unit is inside the sample segment or outside the segment. Refer to the appropriate segment map.

a. If the housing unit at the address shown in Section A is inside the sample segment, proceed as follows:

   i. Follow the latest version of the count and list procedure. List in Part B of the gold worksheet each housing unit address as you proceed, checking each against the full Donnelley list for the segment. Stop with the first housing unit that also appears on the Donnelley list for the segment. If more than 10 lines would be required, list the first 10 housing units and record the number of additional lines that would be required to complete the listing. Remember that the last housing unit of the listing should always be a housing unit on the Donnelley list.

   ii. For each address listed in Part B that does not appear on the Donnelley list, complete the assignment information in Section A of the pink control card labeled "Missing Household Units." Note the relationship of the missing housing to the starting unit and either administer the screening questionnaire or obtain the correct home telephone number so that a followup contact can be made by telephone. Remember that any resident of the housing unit who is at least 16 years of age is a qualified respondent for the screener. Use only household members, neighbors, or the information operator to get a telephone number; we want to be sure that we have the correct telephone number. Names on mailboxes and addresses can be used with a current phone book to get phone numbers.

   iii. As addresses were listed and counted in Part B in search of a housing unit on the Donnelley list, you may have found it necessary to list and/or count all housing units on one or more block faces.* If so, document each occurrence of this situation with the following information:

(a) the total number of housing units on the block face (that were all listed and/or counted), and

(b) the line numbers, if any, in Part B that correspond to these housing units.

b. If the housing unit at the address shown in Section A is outside the sample segment, proceed as follows:

i. Following the count and list procedure, list in Part B of the gold worksheet each housing unit address you visit until one of the following conditions is satisfied:

(a) you have proceeded one mile, or

(b) you have reached a corner at which you could make a right turn, or

(c) you list exactly one housing unit that also appears on the Donnelley list for the segment. If more than 10 lines would be required, list the first 10 housing units and record the number of additional lines that would be required to complete the listing (as specified in a, b, or c above). Remember that the last housing unit in the listing should always be a housing unit on the Donnelley list.

ii. If you stopped listing housing units in Part B because of condition (a) or condition (b), document this fact in Section C of the gold worksheet and then continue as in a. ii and a. iii of these instructions. If you stopped listing housing units in Part B because of condition (c), continue as in a. ii and a. iii of these instructions.

3. When you complete a screener, indicate a final result code from Figure 1 on the top center of the first page of the screener. Place a heavy circle around the code on the screener. Also place the result code in the result code column in Section C of the pink control card.

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*A block face includes all housing units between the two intersections that define one side of a block.

CONTROL CARD - NO PREVIOUS TELEPHONE CONTACT

A. ASSIGNMENT INFORMATION

CASE ID # ____________ SEG # ____________

TRACT ________________ BLOCKGROUP ______

OLD PHONE # (___) ___ - __________

NEW PHONE # (___) ___ - __________

Name ______________________________

Address __________________ Apt. ______

City ______________________________

SUCCESSFUL SCREEN ______ YES ______ NO

COMMENTS ______________________________

____

____

B. SCHEDULE OF CALLS / VISITS

TIME OF DAY	DAY OF WEEK BEGINNING WITH SUNDAY:						
	SUN	MON	TUE	WED	THU	FRI	SAT
Before Noon							
Noon to 2 p.m.							
2 p.m. to 5 p.m.							
5 p.m. to 7 p.m.							
7 p.m. to 9 p.m.							
After 9 p.m.							

TIME OF DAY	DAY OF WEEK BEGINNING WITH SUNDAY:						
	SUN	MON	TUE	WED	THU	FRI	SAT
Before Noon							
Noon to 2 p.m.							
2 p.m. to 5 p.m.							
5 p.m. to 7 p.m.							
7 p.m. to 9 p.m.							
After 9 p.m.							

C. RECORD OF CALLS / VISITS

CALL NO.	FI ID	RESULT CODE	COMMENTS
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

WORK SHEET

CASES WITH NO PREVIOUS TELEPHONE CONTACT

FI Name: ________________________________ FI ID #: _ _ _ _ _ _

Date	Segment #	Case #	Address	Phone #	Completed Screener
					☐
					☐
					☐
					☐
					☐
					☐
					☐
					☐
					☐
					☐
					☐
					☐
					☐
					☐
					☐
					☐
					☐
					☐
					☐

CONTROL CARD – MISSING HOUSEHOLD UNITS

A. ASSIGNMENT INFORMATION

CASE ID # ____________ SEG # __________

PHONE # (___) ____ - ____________

Name ______________________________

Address ____________________ Apt. # ___

City ______________________________

SUCCESSFUL SCREEN ______ YES ______ NO

Relationship to Identified
Household ________ (1st, 2nd, ... 10th)

Comments ______________________________

____

____

B. SCHEDULE OF CALLS/VISITS

TIME OF DAY	DAY OF WEEK BEGINNING WITH SUNDAY:						
	SUN	MON	TUE	WED	THU	FRI	SAT
Before Noon							
Noon to 2 p.m.							
2 p.m. to 5 p.m.							
5 p.m. to 7 p.m.							
7 p.m. to 9 p.m.							
After 9 p.m.							

TIME OF DAY	DAY OF WEEK BEGINNING WITH SUNDAY:						
	SUN	MON	TUE	WED	THU	FRI	SAT
Before Noon							
Noon to 2 p.m.							
2 p.m. to 5 p.m.							
5 p.m. to 7 p.m.							
7 p.m. to 9 p.m.							
After 9 p.m.							

C. RECORD OF CALLS/VISITS

CALL NO.	FI ID	RESULT CODE	COMMENTS
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

WORKSHEET - MISSING HOUSEHOLD UNITS

A. Initial Housing Unit Information

Case ID # ____________________
Census Tract ____ Block Group __
SEG # ________________________
Name _________________________
Street Address _______________
________________ Apt. # ______
City _________ State _________

B. Linked Housing Units

	Address	Phone Number	Completed Screener
1)	____________________	____________	☐
2)	____________________	____________	☐
3)	____________________	____________	☐
4)	____________________	____________	☐
5)	____________________	____________	☐
6)	____________________	____________	☐
7)	____________________	____________	☐
8)	____________________	____________	☐
9)	____________________	____________	☐
10)	____________________	____________	☐

C. Documentation: ____
____
____
____
____
____

APPENDIX I

CONTROL CARDS FOR PERSONAL MONITORING ACTIVITIES

MONITORING OF CO EXPOSURE—PHASE II
CONTROL CARD

A. ASSIGNMENT INFORMATION

CASE # ____________ GROUP # ____________
PID # ____________
PHONE # (____) ____ - ____________

First name ____________ Age ______
Address ____________ Apt. # ______
City ____________

Date 1 ____________
Date 2 ____________
Date 3 ____________

D. INTERVIEWER VISIT INFORMATION

Day ______ **Date** ______ **Time** ______**p.m.**
Location ____________

Special Instructions: ____________

Full Name of Respondent: ____________

B. SCHEDULE OF CALLS

TIME OF DAY	DAY OF WEEK BEGINNING WITH SUNDAY:						
	SUN	MON	TUE	WED	THU	FRI	SAT
Before Noon							
Noon to 2 p.m.							
2 p.m. to 5 p.m.							
5 p.m. to 7 p.m.							
7 p.m. to 9 p.m.							
After 9 p.m.							

TIME OF DAY	DAY OF WEEK BEGINNING WITH SUNDAY:						
	SUN	MON	TUE	WED	THU	FRI	SAT
Before Noon							
Noon to 2 p.m.							
2 p.m. to 5 p.m.							
5 p.m. to 7 p.m.							
7 p.m. to 9 p.m.							
After 9 p.m.							

C. RECORD OF CALLS

CALL NO.	TI ID	RESULT CODE	COMMENTS
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

To Field Interviewer: ____________ **I.D. No.:** ________ **Date:** ________

E. RECORD OF FIELD CONTACTS

DATE	TIME	TYPE	RESULT CODE	NOTES
		TC		
	pm	A		
	pm	PV		
		TC		
	pm	A		
	pm	PV		

CODES:

TELEPHONE CONTACT (TC)		APPOINTMENT (A)		PICK-UP VISIT (PU)	
01	Complete	11	Kept	21	Case complete
02	No contact	12	Not kept—no reschedule	22	Partial data
03	Reschedule	13	Not kept—reschedule	25	Other: ____________
04	Refusal	14	Refusal		____________

F. PEM CONTROL

PEM number ______________________ Issued by ______________ Date __________

Checked in by ______________________ Date ______________

G. DOCUMENT CONTROL

ITEM CHECKLIST	1. FI USE	2. FS USE Date received:	3. OFFICE USE Date received:	Batch number or file
a. Control card	☐	☐	☐	
b. Consent/Incentive form	☐	☐	☐	
c. Study questionnaire	☐	☐	☐	
d. Activity diary	☐	☐	☐	
e. Monitor data output	☐	☐	☐	

NOTES: ____

____

____

SECOND DAY CONTROL CARD

PID ____________________

E. RECORD OF FIELD CONTACTS

DATE	TIME	TYPE	RESULT CODE	NOTES
		TC		
	pm	A		
	pm	PV		
		TC		
	pm	A		
	pm	PV		

CODES:

TELEPHONE CONTACT (TC)

- 01 Complete
- 02 No contact
- 03 Reschedule
- 04 Refusal

APPOINTMENT (A)

- 11 Kept
- 12 Not kept—no reschedule
- 13 Not kept—reschedule
- 14 Refusal

PICK-UP VISIT (PU)

- 21 Case complete
- 22 Partial data
- 25 Other: ____________
  ____

F. PEM CONTROL

PEM number ____________________ Issued by ____________ Date ____________

Checked in by ____________________ Date ____________

G. DOCUMENT CONTROL

ITEM CHECKLIST	1. FI USE	2. FS USE	3. OFFICE USE	
		Date received:	Date received:	Batch number or file
a. Control card	☐	☐	☐	
b. Consent/Incentive form	☐	☐	☐	
c. Study questionnaire	☐	☐	☐	
d. Activity diary	☐	☐	☐	
e. Monitor data output	☐	☐	☐	

NOTES: ____

____

____

APPENDIX J

TABULATION OF SUMMARY SHEET DATA

TABULATION OF RESULT CODES ENTERED ON SUMMARY SHEETS

	Subject					PEM					Diary					Breath sample				
Date	11	12	13	14	15	21	22	23	24	25	31	32	33	34	35	41	42	43	44	45
11-1	10	0	0	0	0	10	0	0	0	0	7	2	1	0	0	6	0	4	0	0
11-2	10	0	0	0	0	9	1	0	0	0	9	1	0	0	0	8	0	2	0	0
11-3	8	0	1	1	0	4	4	0	0	0	4	4	0	0	0	8	0	0	0	0
11-4	8	0	1	1	0	4	1	3	0	0	8	0	0	0	0	8	0	0	0	0
11-5	8	3	1	0	0	6	0	2	0	0	5	3	0	0	0	8	0	0	0	0
11-6	8	3	1	0	0	5	1	2	0	0	5	0	3	0	0	8	0	0	0	0
11-9	10	0	1	0	0	4	6	0	0	0	7	2	1	0	0	10	0	0	0	0
11-10	10	0	1	0	0	9	1	0	0	0	8	1	1	0	0	9	0	1	0	0
11-11	11	0	1	0	0	11	0	0	0	0	9	0	2	0	0	11	0	0	0	0
11-12	11	0	1	0	0	10	1	0	0	0	7	1	3	0	0	10	0	0	0	1
11-13	7	0	1	0	0	7	0	0	0	0	5	1	1	0	0	7	0	0	0	0
11-14	7	0	1	0	0	5	1	1	0	0	5	0	2	0	0	7	0	0	0	0
11-15	9	0	2	0	0	9	0	0	0	0	9	0	0	0	0	9	0	0	0	0
11-16	9	0	2	0	0	8	0	1	0	0	8	0	1	0	0	9	0	0	0	0
11-17	6	3	2	0	0	4	1	1	0	0	5	0	1	0	0	5	0	0	0	1
11-18	5	4	2	0	0	5	0	0	0	0	5	0	0	0	0	5	0	0	0	0
11-19	9	0	2	0	0	8	1	0	0	0	9	0	0	0	0	9	0	0	0	0
11-20	9	0	2	0	0	8	1	0	0	0	9	0	0	0	0	9	0	0	0	0
11-21	9	0	2	0	0	6	3	0	0	0	6	3	0	0	0	8	0	0	0	1
11-22	9	0	2	0	0	3	6	0	0	0	7	2	0	0	0	9	0	0	0	0
11-29	7	0	3	0	0	6	1	0	0	0	7	0	0	0	0	7	0	0	0	0
11-30	7	0	3	0	0	6	1	0	0	0	7	0	0	0	0	7	0	0	0	0
12-1	7	0	4	0	0	1	6	0	0	0	7	0	0	0	0	7	0	0	0	0
12-2	7	0	4	0	0	6	0	0	0	1	5	0	2	0	0	7	0	0	0	0
12-3	10	0	1	0	0	7	2	1	0	0	10	0	0	0	0	10	0	0	0	0
12-4	10	0	1	0	0	10	0	0	0	0	10	0	0	0	0	10	0	0	0	0
12-5	10	0	1	0	0	9	0	1	0	0	9	1	0	0	0	9	0	1	0	0
12-6	10	0	1	0	0	9	1	0	0	0	7	1	2	0	0	10	0	0	0	0
12-7	6	0	5	0	0	6	0	0	0	0	6	0	0	0	0	6	0	0	0	0
12-8	6	0	5	0	0	6	0	0	0	0	6	0	0	0	0	6	0	0	0	0
12-9	9	0	3	0	0	8	0	1	0	0	9	0	0	0	0	9	0	0	0	0

(continued)

	Subject				PEM						Diary					Breath sample				
Date	11	12	13	14	15	21	22	23	24	25	31	32	33	34	35	41	42	43	44	45
12-10	9	0	3	0	0	8	1	0	0	0	8	1	0	0	0	9	0	0	0	0
12-11	8	0	3	0	0	8	0	0	0	0	8	0	0	0	0	8	0	0	0	0
12-12	8	0	3	0	0	7	1	0	0	0	7	0	1	0	0	7	0	1	0	0
12-13	7	1	3	0	0	5	2	0	0	0	5	0	2	0	0	7	0	0	0	0
12-14	6	2	3	0	0	5	1	0	0	0	4	0	2	0	0	6	0	0	0	0
12-15	8	0	3	0	0	7	0	1	0	0	8	0	0	0	0	8	0	0	0	0
12-16	8	0	3	0	0	7	1	0	0	0	8	0	0	0	0	8	0	0	0	0
12-17	4	0	2	0	0	4	0	0	0	0	3	0	1	0	0	4	0	0	0	0
12-18	4	0	2	0	0	4	0	0	0	0	3	0	1	0	0	4	0	0	0	0
12-19	8	0	2	0	0	7	1	0	0	0	6	2	0	0	0	8	0	0	0	0
12-20	8	0	2	0	0	4	3	1	0	0	5	3	0	0	0	8	0	0	0	0
12-21	3	0	0	0	0	3	0	0	0	0	3	0	0	0	0	3	0	0	0	0
12-22	3	0	0	0	0	3	0	0	0	0	3	0	0	0	0	3	0	0	0	0
1-5	12	0	0	0	0	9	1	2	0	0	6	3	3	0	0	12	0	0	0	0
1-6	12	0	0	0	0	10	2	0	0	0	12	0	0	0	0	12	0	0	0	0
1-7	8	1	3	0	1	7	1	0	0	0	7	0	1	0	0	8	0	0	0	0
1-8	7	1	3	0	1	7	0	0	0	0	6	0	1	0	0	7	0	0	0	0
1-9	10	0	2	0	0	9	1	0	0	0	10	0	0	0	0	10	0	0	0	0
1-10	10	0	2	0	0	7	1	2	0	0	9	0	0	0	1	10	0	0	0	0
1-11	11	0	1	0	0	11	0	0	0	0	6	0	5	0	0	10	0	0	1	0
1-12	11	0	1	0	0	9	1	1	0	0	11	0	0	0	0	11	0	0	0	0
1-13	11	0	1	0	0	10	1	0	0	0	9	1	1	0	0	11	0	0	0	0
1-14	9	0	1	0	2	6	3	0	0	0	8	0	1	0	0	9	0	0	0	0
1-15	10	0	0	0	0	9	1	0	0	0	9	0	1	0	0	10	0	0	0	0
1-16	10	0	0	0	0	8	2	0	0	0	10	0	0	0	0	10	0	0	0	0
1-17	11	1	0	0	0	8	3	0	0	0	9	2	0	0	0	11	0	0	0	0
1-18	10	1	0	0	1	10	0	0	0	0	9	1	0	0	0	10	0	0	0	0
1-19	8	0	3	0	0	7	1	0	0	0	7	1	0	0	0	8	0	0	0	0
1-20	8	0	3	0	0	6	2	0	0	0	8	0	0	0	0	7	0	0	0	1
1-21	8	0	1	0	0	6	2	0	0	0	7	1	0	0	0	8	0	0	0	0
1-22	8	0	1	0	0	8	0	0	0	0	7	1	0	0	0	8	0	0	0	0

(continued)

Date	Subject					PEM					Diary					Breath sample				
	11	12	13	14	15	21	22	23	24	25	31	32	33	34	35	41	42	43	44	45
1-23	10	0	2	0	1	4	3	3	0	0	10	0	0	0	0	10	0	0	0	0
1-24	10	0	2	0	0	9	1	0	0	0	10	0	0	0	0	10	0	0	0	0
1-25	12	0	0	0	0	11	1	0	0	0	10	0	2	0	0	11	0	1	0	0
1-26	12	0	0	0	0	11	1	0	0	0	10	1	1	0	0	12	0	0	0	0
1-27	11	0	1	0	0	11	0	0	0	0	10	0	1	0	0	10	0	1	0	0
1-28	11	0	1	0	0	8	3	0	0	0	8	0	2	0	0	11	0	0	0	0
1-29	7	0	0	0	3	7	0	0	0	0	6	1	0	0	1	7	0	0	0	0
1-30	7	0	0	0	3	4	3	0	0	0	5	1	1	0	0	7	0	0	0	0
1-31	11	0	1	0	0	11	0	0	0	0	6	5	0	0	0	11	0	0	0	0
2-1	11	0	1	0	0	11	0	0	0	0	6	3	2	0	0	11	0	0	0	0
2-2	12	0	0	0	0	12	0	0	0	0	9	3	0	0	0	11	0	0	0	1
2-3	11	1	0	0	0	9	2	0	0	0	10	0	1	0	0	11	0	0	0	0
2-4	10	1	1	0	0	9	1	0	0	0	10	0	0	0	0	10	0	0	0	0
2-5	10	1	1	0	0	9	1	0	0	0	10	0	0	0	0	9	0	1	0	0
2-6	5	0	3	0	4	3	1	1	0	0	5	0	0	0	0	4	0	1	0	0
2-7	5	0	3	0	4	4	0	1	0	0	3	2	0	0	0	5	0	0	0	0
2-8	10	2	1	0	0	9	0	1	0	0	9	0	0	0	0	9	0	0	0	1
2-9	10	2	1	0	0	8	1	1	0	0	8	1	0	0	1	7	0	3	0	0
2-10	9	0	2	0	0	9	0	0	0	0	8	1	0	0	1	9	0	0	0	0
2-11	9	0	2	0	0	7	1	1	0	0	8	1	0	0	0	9	0	0	0	0
2-12	13	0	1	0	0	10	3	0	0	0	11	1	1	0	0	12	0	1	0	0
2-13	13	0	1	0	0	12	1	0	0	0	13	0	0	0	0	13	0	0	0	0
2-14	12	0	2	0	1	10	0	2	0	0	11	1	0	0	0	10	1	1	0	0
2-15	11	1	2	0	1	11	0	0	0	0	11	0	0	0	0	7	0	4	0	0
2-16	13	0	0	0	1	11	2	0	0	0	11	2	0	0	0	13	0	0	0	0
2-17	13	0	0	0	1	11	1	1	0	0	12	1	0	0	0	10	0	2	0	1
2-18	9	1	4	0	0	6	3	0	0	0	9	0	0	0	0	9	0	0	0	0
2-19	9	1	4	0	0	8	1	0	0	0	9	0	0	0	0	9	0	0	0	0
2-20	11	0	4	0	0	7	2	2	0	0	7	3	1	0	0	10	0	1	0	0

(continued)

	Subject					PEM					Diary					Breath sample				
Date	11	12	13	14	15	21	22	23	24	25	31	32	33	34	35	41	42	43	44	45
2-21	11	0	4	0	0	10	0	1	0	0	11	0	0	0	0	11	0	0	0	0
2-22	13	0	0	0	2	11	0	0	0	2	13	0	0	0	0	13	0	0	0	0
2-23	13	0	0	0	2	11	0	2	0	0	13	0	0	0	0	11	0	2	0	0
2-24	11	0	0	0	4	8	2	1	0	0	11	0	0	0	0	10	0	0	0	1
2-25	11	0	0	0	4	10	1	0	0	0	11	0	0	0	0	8	0	2	0	1
2-26	12	1	0	0	3	10	2	0	0	0	11	1	0	0	0	11	0	1	0	0
2-27	12	1	0	0	3	10	2	0	0	0	12	0	0	0	0	12	0	0	0	0
Total	900	32	120	0	41	750	110	37	0	3	778	66	52	0	4	859	1	30	1	9

APPENDIX K

LAND USE CATEGORIES[a] DEFINED BY DENVER REGIONAL COUNCIL OF GOVERNMENTS

SF - Single Family Residential

Includes dwelling units, other than mobile homes, normally used as a dwelling place by one family, accessory buildings, and yard space. Land associated with farm dwellings is included within this category to the extent of one acre, except when precise delineation of nonagricultural land areas directly associated with the dwelling is possible.

MF - Multifamily Residential

Land and associated structures where two or more families or households have their dwelling. Includes accessory building and yard space. Excluded from this category are structures primarily intended for transient use. Included in this category are townhouses, duplexes, high rise apartments, and group quarters.

MH - Mobile Homes

CR - Retail Commercial - Regional Shopping Center

Retail areas covering an area of at least 30 acres or including at least 400,000 square feet of gross floor area.

C - Commercial (other)

Establishments and associated land, the main purpose of which is the retailing of goods and services to the general public. Included in this category are dwellings intended for transient use, general retail business, personal and commercial services, restaurants, and commercial entertainment services.

O - Office

Includes structures and associated land, the main purpose of which is the provision of office-type activities and services. Included are administrative services, government offices, finance, real estate, insurance operations, business servcies, and professional services. Also included are sales offices and branches, offices of agents and brokers primarily engaged in wholesale distribution but with no warehousing except samples.

PU - Public and Semipublic

Included are structures, operations, and land which are financed by public funds and operated as part of the governmental function. In addition uses which are operated by private individuals or institutions for a public purpose, but with limited public control or access are included. Included uses are cultural, educational, medical, protective, and correctional facilities, cemetaries, and military installations. Excluded are administrative offices of government - these are included in the Office category of land use.

IT - Industrial, Transportation, Communication

Structures and associated land concerned with the manufacturing, treatment, processing, fabrication, or bulk storage of goods or materials. Included are mining and quarrying operations and those nonmanufacturing industrial uses which are connected with heavy repair, open air storage, and warehousing. Also included are lands and structures utilized for the conveyance of passengers and freight from place to place (railroads and freeways), transportation equipment maintenance, transportation services, and automobile parking not directly related with other use. In addition, structures and lands used for the collection and distribution system of utilities and communications facilities such as telephone and telegraph systems, radio and electric utilities systems, post offices, utilities, water supply systems, sewerage systems, and disposal facilities.

A Agriculture

Included are land and structures associated with the growing of agricultural crops, plants, and trees, and the keeping, grazing, and feeding of livestock. Included are greenhouses, nurseries, fish hatcheries, and feedlots.

F - Forest

Includes land, other than parklands, which are forested. Both public and privately owned forest lands and included. National Forests are included in this category.

P - Parks and Recreation

Included in this category are lands, waters, and structures developed for active or passive recreation. Included are facilities such as stadiums, coliseums, gymnasiums, race tracks, tennis courts, golf courses, parks, campgrounds, opensapces, and greenbelts. Both private and publicly owned park and recreation areas are included.

V - Vacant

Included are both lands and structures characterized by the absence of any activity.

S - Special

Lakes, other than those within parklands, are included in this category.

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[a] Land Use in the Denver Metropolitan Area, Denver Regional Council of Governments, Denver, Colorado, November 1981.

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APPENDIX L

LAND USE STATISTICS BY CENSUS TRACT

ST	CNTY	TRACT	RES	RA	RDEN	WTC	WTI	WA	IDEN
8	31	1 1	3216	181.0	17.77	1456	242	126.1	5.53
8	31	1 2	3441	256.8	13.40	724	233	30.1	3.35
8	31	2 1	3513	292.0	12.03	1726	2542	172.4	9.19
8	31	2 2	4394	254.7	17.25	1203	1972	165.8	7.55
8	31	3 1	5297	384.9	13.76	2273	743	83.2	6.44
8	31	3 2	3852	286.8	13.43	1078	836	62.6	5.48
8	31	3 3	5465	298.1	18.33	2663	847	51.1	10.05
8	31	4 1	3513	212.3	16.55	730	109	24.5	3.54
8	31	4 2	6689	267.5	25.01	1434	2025	147.1	8.34
8	31	5 1	2020	141.8	14.25	0	0	12.7	5.91
8	31	5 2	5843	318.4	18.35	0	0	57.4	5.91
8	31	6 0	2498	109.3	22.85	1119	2676	143.2	15.03
8	31	7 1	3702	196.2	18.87	1933	2398	68.9	16.34
8	31	7 2	6005	223.6	26.86	1222	1722	87.1	9.48
8	31	8 0	2160	9.2	234.78	358	4183	350.9	12.61
8	31	9 1	7419	472.8	15.69	3653	975	75.8	8.44
8	31	9 2	4928	396.4	12.43	968	479	34.7	3.35
8	31	9 3	4717	361.8	13.04	2067	707	54.8	6.66
8	31	10 0	3381	157.9	21.41	1546	3766	305.1	11.47
8	31	11 1	2908	135.4	21.48	956	614	66.5	7.83
8	31	11 2	3114	111.4	27.95	1095	985	151.8	7.90
8	31	13 1	3902	319.5	12.21	1318	857	98.1	5.21
8	31	13 2	3432	237.1	14.47	1793	1722	234.4	7.45
8	31	14 1	4781	290.4	16.46	1856	1321	146.9	7.27
8	31	14 2	3917	223.2	17.55	1955	238	51.3	7.99
8	31	14 3	2182	151.2	14.43	1075	3474	329.2	9.47
8	31	15 0	3654	152.5	23.96	998	8771	1012.3	8.39
8	31	16 0	3960	60.8	65.13	489	6462	636.3	9.97
8	31	17 1	609	4.9	124.29	248	6054	213.2	28.90
8	31	17 2	2030	6.0	338.33	1357	36254	244.0	150.44
8	31	18 0	2353	66.1	34.08	247	4791	134.4	25.13
8	31	19 0	3639	53.8	67.64	437	6695	784.9	8.56
8	31	20 0	751	14.7	51.09	0	5870	144.7	36.83
8	31	21 0	6177	205.8	30.01	2540	12582	689.3	16.89
8	31	23 0	5343	269.3	19.84	1275	246	58.3	4.64
8	31	24 1	3131	90.1	34.75	618	631	46.8	9.12
8	31	24 2	2005	66.6	30.11	376	853	26.8	13.16
8	31	25 0	1004	17.9	56.09	216	477	33.4	13.51
8	31	26 1	2656	22.8	116.49	1120	9427	97.1	87.96
8	31	26 2	1670	32.8	50.91	866	2443	54.5	37.90
8	31	27 1	4392	57.8	75.99	2243	4372	74.4	50.04
8	31	27 2	4980	98.9	50.35	2893	4143	50.2	47.19
8	31	27 3	5057	93.2	54.26	1974	1334	33.4	26.13
8	31	28 1	2879	141.1	20.40	1127	989	29.1	12.43
8	31	28 2	4567	148.4	30.77	2446	1572	62.7	19.03
8	31	28 3	3983	123.3	32.30	2353	241	10.6	19.37
8	31	29 1	2956	159.6	18.52	1106	1091	75.5	9.34
8	31	29 2	4118	289.1	14.24	873	113	17.8	3.21
8	31	30 1	5647	428.8	13.17	3417	1611	85.5	9.78
8	31	30 2	2521	177.1	14.23	3023	2185	83.7	19.97
8	31	30 3	3414	159.3	21.43	854	478	114.3	4.87
8	31	30 4	4519	250.2	18.06	2849	2160	99.0	14.34
8	31	30 5	1422	147.2	9.66	715	124	15.7	5.15
8	31	31 1	1943	83.2	23.35	1803	1804	39.3	29.44
8	31	31 2	3494	95.4	36.62	1730	4419	103.7	30.88

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8	31	32 1	5327	99.1	53.39	3489	727	11.2	38.12
8	31	32 2	3108	81.4	38.18	1479	374	12.7	19.69
9	31	32 3	3153	300.2	10.50	745	363	109.6	2.72
8	31	33 0	3224	239.5	13.46	3167	253	46.3	11.97
8	31	34 0	6909	535.1	12.91	2815	933	178.0	5.33
8	31	35 0	5258	286.9	18.33	1485	7573	1096.2	6.55
8	31	36 1	4929	184.2	26.75	978	622	132.1	5.16
8	31	36 2	4622	252.8	18.28	1907	2669	195.5	10.21
8	31	36 3	3620	243.1	14.39	786	552	35.4	4.66
8	31	37 1	2271	71.6	31.72	1191	2426	51.8	29.31
8	31	37 2	4562	159.0	28.69	2479	437	13.1	16.75
8	31	37 3	3217	130.5	24.65	1368	1084	35.5	14.77
8	31	38 0	3921	287.1	13.66	1355	6493	201.4	17.09
8	31	39 1	3520	500.5	7.03	845	1221	128.5	3.28
8	31	39 2	3742	332.5	11.25	1226	2173	193.2	6.47
8	31	40 2	3341	406.5	8.22	0	0	18.8	5.53
8	31	40 3	4809	546.5	8.80	0	0	64.2	5.53
8	31	40 4	1880	221.0	8.51	0	0	118.6	5.53
8	31	40 5	2655	175.9	14.84	0	0	85.0	5.53
8	31	40 6	4205	384.6	10.93	0	0	53.6	5.53
8	31	41 1	3406	145.7	23.39	0	0	756.1	3.60
8	31	41 2	4792	241.6	19.83	0	0	548.7	3.60
8	31	41 3	6473	450.5	14.37	0	0	19.4	3.60
8	31	41 4	5426	437.2	12.41	0	0	43.1	3.60
9	31	41 5	661	.0	.00	0	0	5061.4	3.60
8	31	42 1	5072	413.0	12.28	3148	2055	55.3	11.11
8	31	42 2	4188	394.4	10.62	1106	497	85.0	3.34
8	31	43 1	5057	216.7	23.34	4147	7745	120.5	35.27
8	31	43 2	2563	245.4	10.44	2303	369	26.2	9.84
8	31	43 3	3992	499.4	7.99	1368	355	53.7	3.12
8	31	43 4	5690	543.3	10.47	3121	1571	90.5	7.40
8	31	43 5	4056	383.5	10.58	2223	366	14.9	6.50
8	31	44 1	8736	574.5	15.20	3842	490	56.4	6.85
8	31	44 2	6390	.0	.00	994	8017	1689.0	5.34
8	31	45 1	5683	715.5	7.94	1558	233	79.0	2.27
8	31	45 2	6199	345.1	17.96	2989	890	123.3	8.28
8	31	46 1	4974	421.3	11.79	1946	727	45.7	5.72
8	31	46 2	5351	318.7	16.79	3022	976	82.2	9.97
8	31	46 3	5046	386.5	13.06	1115	120	69.2	2.71
8	31	47 0	5688	429.0	13.26	3428	722	121.1	7.54
8	31	48 1	3143	282.5	11.12	1706	357	64.7	5.94
8	31	48 2	4272	274.8	15.55	1198	113	205.7	2.73
8	31	49 0	2525	184.0	13.72	1447	874	47.3	10.03
8	5	4950	2946	93.5	31.51	1327	2725	164.8	15.69
8	31	50 1	2722	193.1	14.10	0	0	92.6	8.39
8	31	50 2	5611	338.9	16.56	0	0	149.2	8.39
8	31	51 2	3960	328.1	12.07	0	0	47.3	13.69
8	31	51 3	2799	90.7	30.86	0	0	44.2	13.69
8	31	51 4	3020	106.5	28.36	0	0	64.6	13.69
8	31	52 0	3595	318.6	11.28	1716	968	86.0	6.63
8	31	53 0	1372	116.3	11.74	248	2561	145.3	10.71
8	5	5350	294	70.0	4.20	120	119	.0	3.41
8	31	54 1	196	7.7	25.45	0	1310	317.5	4.13
8	31	54 2	3910	370.1	10.56	1200	1683	101.9	6.11
8	5	54 3	630	82.1	7.67	247	1714	249.1	5.92
8	31	55 2	1098	51.7	21.24	1333	961	530.7	3.94
8	31	55 3	4678	400.4	11.68	473	130	14.8	1.45

8	5	5551	1232	181.0	6.31	843	1096	237.5	4.63
8	5	5552	2596	165.5	15.69	1405	560	187.2	6.42
8	5	5553	3490	293.2	11.70	943	739	224.0	3.17
8	5	56 2	5910	962.2	6.14	0	0	110.4	2.59
8	5	56 7	5539	312.2	6.82	0	0	145.5	2.59
8	5	56 8	3597	639.6	5.62	0	0	447.6	2.59
8	5	56 9	3173	348.5	9.10	0	0	39.7	2.59
8	5	5610	7509	671.1	11.19	0	0	201.1	2.59
8	5	5611	5771	755.3	7.64	0	0	117.2	2.59
8	5	5612	3428	644.7	5.32	0	0	136.3	2.59
8	5	5613	4838	601.4	8.04	0	0	26.8	2.59
8	5	5614	3312	392.9	8.43	0	0	204.4	2.59
8	5	5615	7492	821.1	9.12	0	0	61.1	2.59
8	5	5616	6073	575.9	10.55	0	0	106.4	2.59
8	5	57 0	2998	407.5	7.36	913	6217	174.5	12.23
8	5	58 0	2941	272.5	10.79	2249	632	10.2	10.19
8	31	59 0	0	477.4	.00	3253	2158	91.7	9.68
8	5	60 0	3110	231.6	13.43	1694	2270	404.2	6.23
8	5	61 0	2947	214.5	13.74	929	439	61.0	4.78
8	5	62 0	3421	309.5	11.05	1420	1204	312.0	4.22
8	5	63 0	2926	278.3	10.51	1435	239	45.7	5.17
8	5	64 0	3059	223.8	13.67	974	1563	275.2	5.12
8	5	65 1	825	120.2	6.86	0	0	215.2	6.04
8	5	65 2	3482	383.9	9.07	0	0	82.0	6.04
8	5	66 1	4146	274.3	15.09	0	0	175.6	7.38
8	5	66 3	3773	388.1	9.72	0	0	65.5	7.38
8	5	66 4	3944	413.3	9.54	0	0	33.4	7.38
8	31	67 1	0	.0	.00	0	0	6.2	2.78
8	5	67 2	6039	757.7	7.97	0	0	292.7	2.78
8	5	67 3	13936	1469.8	9.48	0	0	147.6	2.78
8	5	67 4	3298	1596.4	2.07	0	0	85.2	2.78
8	5	67 5	1829	938.1	1.95	0	0	20.2	2.78
8	31	68 2	4744	380.9	12.45	0	0	74.8	4.04
8	31	68 4	1231	119.5	10.30	0	0	88.7	4.04
8	5	68 6	10	10.3	.97	0	0	702.8	4.04
8	5	68 7	1029	237.4	4.33	0	0	206.7	4.04
8	5	68 8	8106	892.3	9.08	0	0	52.8	4.04
8	31	68 9	6056	471.7	12.84	0	0	130.6	4.04
8	31	6810	4625	344.7	13.42	0	0	92.7	4.04
8	31	6811	5325	333.4	15.97	0	0	100.2	4.04
8	31	6812	2432	196.1	12.40	0	0	39.6	4.04
8	5	6854	1676	316.8	5.29	0	0	199.1	4.04
8	31	69 1	5376	276.3	19.42	3290	2348	188.4	12.01
8	31	69 2	1230	90.4	13.61	265	608	41.6	6.61
8	5	6951	1220	201.3	6.04	1094	113	14.9	5.54
8	5	6952	1299	112.6	11.54	120	0	18.7	.91
8	31	70 1	7567	347.5	21.77	0	0	598.3	2.82
8	5	70 3	4690	422.1	11.11	0	0	104.9	2.82
8	31	70 6	2224	69.3	31.86	0	0	29.1	2.82
8	5	70 7	4169	289.2	14.42	0	0	101.7	2.82
8	5	70 8	4918	391.3	12.55	0	0	84.0	2.82
8	5	7012	2965	492.8	6.02	0	0	143.0	2.82
8	31	7013	212	33.1	6.40	0	0	111.4	2.82
8	5	7015	3013	221.3	13.62	0	0	24.5	2.82
8	5	7016	2857	242.3	11.79	0	0	44.9	2.82
8	5	7017	4515	376.7	11.99	0	0	30.0	2.82
8	5	7018	2459	154.1	15.96	0	0	40.1	2.82

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8	5	7019	4010	301.5	13.30	0	0	17.6	2.82
8	5	7020	3298	283.2	11.65	0	0	78.0	2.82
8	5	7021	3214	377.0	8.53	0	0	36.3	2.82
8	5	7022	3381	315.2	12.31	0	0	164.0	2.82
8	5	7023	6240	445.7	14.00	0	0	71.4	2.82
8	5	7024	5529	509.2	10.86	0	0	232.0	2.82
8	5	7025	5721	641.5	8.92	0	0	65.0	2.82
8	5	7026	5484	494.9	11.08	0	0	25.3	2.82
8	5	7027	4334	503.1	9.61	0	0	67.2	2.82
8	5	7028	2568	247.0	10.40	0	0	14.2	2.82
8	5	7029	9593	968.1	9.91	0	0	64.8	2.82
8	5	7030	10959	951.5	11.52	0	0	75.2	2.82
8	5	7031	9481	3299.7	2.87	0	0	137.1	2.82
8	5	7054	2644	332.2	7.96	0	0	189.8	2.82
8	5	71 0	4737	913.0	5.19	1604	2827	5978.7	.63
8	5	72 0	7732	451.5	17.12	3534	1455	212.6	7.51
8	5	73 0	6533	185.6	35.20	1684	2949	196.5	12.13
8	5	74 0	4242	367.5	11.54	2526	595	76.1	7.34
8	5	75 0	2297	210.3	10.92	243	118	11.7	1.63
8	5	76 0	2563	214.0	11.98	351	485	50.9	3.19
8	5	77 2	2857	335.8	8.51	0	0	67.0	4.96
8	5	77 3	2632	268.7	9.80	0	0	81.0	4.96
8	5	77 4	2669	157.2	16.98	0	0	14.5	4.96
8	1	73 0	5183	143.3	36.04	1665	2015	171.7	11.66
8	1	79 0	4393	248.7	17.66	2048	987	164.0	7.35
8	1	80 0	4922	342.1	14.39	2281	0	151.8	4.62
8	1	81 0	1895	49.0	38.67	507	2425	394.9	6.61
8	1	82 0	5422	435.4	12.45	3705	495	126.2	7.48
8	31	83 3	0	127.9	.00	0	0	.0	4.22
8	31	83 4	3182	193.5	16.44	0	0	9.4	4.22
8	31	83 5	3574	232.6	15.37	0	0	3.6	4.22
8	31	83 6	4737	268.5	17.64	0	0	9.8	4.22
8	31	83 7	4669	294.9	15.83	0	0	36.0	4.22
8	1	83 8	3748	320.4	11.70	0	0	316.4	4.22
8	1	83 9	2992	271.4	11.02	0	0	243.7	4.22
8	31	8310	5	160.2	.03	0	0	5.5	4.22
8	1	8353	2087	328.6	6.35	0	0	1391.7	4.22
8	1	84 0	3218	510.0	6.31	245	121	234.3	.49
8	1	85 5	8141	638.6	12.75	0	0	90.8	1.74
8	1	85 6	3311	160.0	20.69	0	0	46.7	1.74
8	1	85 7	7856	604.4	13.00	0	0	44.6	1.74
8	1	85 8	4230	391.1	10.82	0	0	95.1	1.74
8	1	85 9	6960	1252.1	5.56	0	0	73.5	1.74
8	1	8510	3373	902.5	3.74	0	0	117.4	1.74
8	1	8511	6103	868.2	7.03	0	0	153.8	1.74
8	1	8512	1287	379.7	3.39	0	0	824.0	1.74
8	1	8513	1775	781.7	2.27	0	0	175.0	1.74
8	1	8514	4444	1994.0	2.23	0	0	909.8	1.74
8	1	86 1	4217	429.4	9.82	2438	1344	135.6	6.69
8	1	86 2	6705	547.0	12.26	2549	2070	329.7	5.27
8	1	87 1	18	.0	.00	0	0	17013.7	.81
8	1	87 3	5429	499.0	10.88	0	0	1302.0	.81
8	1	87 5	4647	326.5	14.23	0	0	205.5	.81
8	1	87 6	4653	387.0	12.02	0	0	73.8	.81
8	1	88 1	4032	384.6	10.48	1046	593	227.2	2.68
8	1	88 2	3734	200.3	18.60	1692	493	1339.4	1.42
8	1	89 1	2563	227.7	11.26	597	3924	1586.6	2.49

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8	1	9952	986	105.2	9.31	117	5170	1662.5	2.99
8	1	90 1	4236	312.6	13.55	0	0	62.1	5.50
8	1	90 2	5334	449.7	11.96	0	0	104.0	5.50
8	1	90 3	1491	174.2	6.56	0	0	85.1	5.50
8	1	91 1	4124	299.4	13.77	0	0	74.8	3.81
8	1	91 2	3063	280.8	10.91	0	0	208.9	3.81
8	1	92 1	3293	430.0	7.66	0	0	34.3	3.29
8	1	92 2	4711	361.8	13.02	0	0	71.1	3.29
8	1	92 3	1963	75.0	26.17	0	0	139.5	3.29
8	1	93 4	5698	519.4	10.97	0	0	128.8	5.87
8	1	93 6	4174	330.3	12.64	0	0	56.4	5.87
8	1	93 7	3381	284.3	11.89	0	0	113.3	5.87
8	1	93 8	4056	304.2	13.33	0	0	52.0	5.87
8	1	93 9	1944	122.7	15.84	0	0	48.4	5.87
8	1	9310	5234	336.1	15.57	0	0	31.7	5.87
8	1	9311	10917	752.8	14.50	0	0	131.5	5.87
8	1	9312	6584	321.1	20.50	0	0	147.3	5.87
8	1	9313	2003	255.2	7.85	0	0	129.4	5.87
8	1	9314	5680	554.7	10.24	0	0	207.5	5.87
8	1	94 1	5418	473.0	11.45	0	0	55.6	3.40
8	1	94 3	1370	249.3	5.50	0	0	40.9	3.40
8	1	94 4	11315	1197.5	9.45	0	0	28.9	3.40
8	1	95 1	3176	202.3	15.66	0	0	66.5	4.63
8	1	95 2	3819	390.6	9.78	0	0	442.7	4.63
8	1	9553	2975	277.2	10.71	0	0	1521.7	4.63
8	1	96 3	5232	389.3	13.44	0	0	23.3	7.24
8	1	96 4	4421	368.1	12.01	0	0	122.3	7.24
8	1	96 5	4536	334.0	13.58	0	0	255.2	7.24
8	1	96 6	2346	180.7	12.98	0	0	281.3	7.24
8	1	9750	5126	545.2	9.40	3183	1605	425.5	4.93
8	59	98 3	9471	1270.5	7.45	0	0	433.0	2.74
8	59	98 4	5001	604.6	8.27	0	0	404.8	2.74
8	59	98 5	3488	612.4	5.70	0	0	759.0	2.74
8	59	98 6	4403	727.5	6.05	0	0	390.1	2.74
8	59	98 7	1882	236.1	7.97	0	0	120.3	2.74
8	59	98 8	3133	227.3	13.75	0	0	138.2	2.74
8	59	9810	5971	601.6	9.93	0	0	390.0	2.74
8	59	9811	5716	684.2	8.35	0	0	385.1	2.74
8	59	9812	7985	736.8	10.84	0	0	96.0	2.74
8	59	9813	12409	1288.4	9.63	0	0	3229.6	2.74
8	59	9814	6575	630.7	10.42	0	0	98.9	2.74
8	59	9815	750	340.1	2.21	0	0	12.8	2.74
8	59	99 0	2437	216.3	11.27	1971	5770	322.9	14.36
8	59	100 0	3629	169.2	21.45	973	3326	375.2	7.90
8	59	101 0	3559	603.5	5.90	1956	737	136.9	3.64
8	59	102 3	10824	903.6	11.98	0	0	103.2	3.80
8	59	102 4	9476	888.0	10.67	0	0	141.7	3.80
8	59	102 5	2751	407.0	6.76	0	0	11.1	3.80
8	59	102 6	4397	314.3	13.97	0	0	147.7	3.80
8	59	102 7	6408	670.8	9.55	0	0	116.5	3.80
8	59	103 3	5142	511.5	10.05	0	0	51.9	6.19
8	59	103 4	3365	248.0	13.57	0	0	40.7	6.19
8	59	103 5	4145	322.2	12.84	0	0	35.4	6.19
8	59	103 6	3278	248.9	13.17	0	0	86.3	6.19
8	59	103 7	4222	303.1	13.93	0	0	43.0	6.19
8	59	103 8	4115	462.7	8.89	0	0	216.8	6.19
8	59	104 2	5965	623.2	9.56	0	0	319.1	4.73

8	59	104 3	4947	717.8	6.89	0	0	156.9	4.73
8	59	104 4	2797	222.0	12.60	0	0	427.0	4.73
8	59	105 2	5519	791.4	6.97	0	0	611.2	5.04
8	59	105 3	4330	509.2	8.50	0	0	63.2	5.04
8	59	105 4	3581	446.4	8.02	0	0	30.9	5.04
8	31	106 1	1084	97.2	11.15	0	0	36.2	7.51
8	59	106 3	3540	396.9	8.92	0	0	78.3	7.51
8	59	106 4	2453	324.7	7.55	0	0	79.3	7.51
8	59	107 0	8716	914.5	9.53	3629	1448	45.9	5.28
8	59	108 1	2683	365.7	7.33	0	0	77.3	7.68
8	59	108 2	2950	273.0	10.81	0	0	158.6	7.68
8	59	109 1	4985	588.0	8.48	0	0	64.9	8.53
8	59	109 2	2557	307.4	8.32	0	0	192.9	8.53
8	59	110 0	5904	808.4	7.41	1714	1772	142.3	3.67
8	59	111 0	5834	685.9	8.51	4030	2822	199.5	7.74
8	59	112 1	1	.0	.00	0	0	735.3	6.98
8	59	112 2	4706	663.0	7.10	0	0	165.1	6.98
8	59	113 0	3331	291.7	11.42	538	473	34.3	3.27
8	59	114 0	4120	344.7	11.95	2874	2878	245.6	9.68
8	59	11550	5305	630.5	8.42	2736	2169	173.4	6.17
8	59	116 1	3586	367.3	9.76	0	0	42.0	3.26
8	59	116 2	3719	380.7	9.77	0	0	82.2	3.26
8	59	117 1	4616	470.2	9.82	0	0	20.7	4.75
8	59	117 2	5653	441.9	12.79	0	0	76.9	4.75
8	59	117 8	5281	533.2	9.90	0	0	35.0	4.75
8	59	117 9	3359	313.9	10.70	0	0	18.6	4.75
8	59	11710	4696	329.5	14.25	0	0	24.4	4.75
8	59	11711	4789	404.2	11.85	0	0	89.6	4.75
8	59	11712	4967	401.0	12.39	0	0	55.7	4.75
8	59	11713	4117	391.1	10.53	0	0	366.7	4.75
8	59	11714	5918	614.3	9.63	0	0	228.3	4.75
8	59	11715	4636	637.0	7.28	0	0	280.0	4.75
8	59	11716	7368	708.5	9.98	0	0	73.3	4.75
8	59	11717	3031	217.7	13.92	0	0	45.4	4.75
8	59	118 1	4942	530.3	9.32	0	0	153.9	5.79
8	59	118 3	4885	353.0	13.84	0	0	84.4	5.79
8	59	118 4	3900	348.7	11.18	0	0	44.6	5.79
8	31	119 2	4427	396.7	11.16	0	0	77.7	5.79
8	31	119 3	2237	195.7	11.43	0	0	18.4	5.79
8	59	119 4	1249	90.9	13.74	0	0	77.2	5.79
8	59	11951	1223	161.1	7.59	0	0	.0	5.79
8	31	120 1	1728	143.5	12.04	0	0	234.4	3.15
8	59	120 3	877	112.0	7.33	0	0	95.0	3.15
8	59	120 6	5322	47.0	113.23	0	0	6.4	3.15
8	59	120 7	1218	23.7	51.39	0	0	21.6	3.15
8	31	12010	415	826.0	.50	0	0	936.9	3.15
8	59	12011	5734	772.1	7.42	0	0	46.2	3.15
8	59	12012	9644	995.4	9.69	0	0	89.4	3.15
8	59	12013	6506	585.5	11.11	0	0	24.1	3.15
8	31	12014	3526	502.8	7.01	0	0	66.2	3.15
8	59	12015	4820	420.1	11.47	0	0	14.0	3.15
8	59	12016	4754	432.5	10.99	0	0	22.1	3.15
8	59	12017	6896	573.1	12.03	0	0	11.6	3.15
8	59	12018	1292	211.5	6.11	0	0	5.2	3.15
8	59	12019	5841	871.1	6.71	0	0	139.2	3.15
8	59	12020	4473	41.9	106.75	0	0	416.2	3.15
8	13	121 1	4837	666.5	7.21	2415	491	54.3	4.23

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8	13	121	2	5950	494.7	12.03	3011	1112	63.8	7.38
8	13	121	3	5291	1075.4	4.92	1393	358	72.9	1.52
8	13	121	4	1370	200.2	6.84	125	123	37.0	1.05
8	13	122	2	4288	199.3	21.46	0	0	185.0	12.12
8	13	122	3	3466	229.1	15.13	0	0	793.2	12.12
8	13	122	4	2080	144.5	14.39	0	0	18.1	12.12
8	13	122	5	3552	149.8	23.71	0	0	165.7	12.12
8	13	123	0	5622	3.2	1756.88	741	6120	375.3	18.13
8	13	124	1	5408	241.8	22.37	2016	1276	29.7	12.13
8	13	124	2	1544	203.0	7.61	971	251	19.8	5.04
8	13	125	1	1973	194.4	10.15	0	0	51.8	5.11
8	13	125	2	3172	316.1	10.03	0	0	41.7	5.11
8	13	125	3	1377	.0	.00	0	0	65.1	5.11
8	13	125	5	4662	487.4	9.57	0	0	155.1	5.11
8	13	125	7	4578	366.2	12.39	0	0	52.5	5.11
8	13	125	8	2699	234.3	11.49	0	0	56.8	5.11
8	13	125	9	3950	324.2	12.18	0	0	106.0	5.11
8	13	125	10	4471	526.2	8.50	0	0	24.5	5.11
8	13	126	2	837	.0	.00	0	0	104.5	6.33
8	13	126	3	3116	313.4	9.94	0	0	31.3	6.33
8	13	126	4	6441	405.5	15.89	0	0	30.7	6.33
8	13	127	1	2377	740.4	3.21	0	0	249.5	2.63
8	13	127	3	2841	1028.4	2.76	0	0	119.1	2.63
8	13	127	4	519	132.2	3.93	0	0	124.4	2.63
8	13	127	5	900	134.1	6.71	0	0	143.4	2.63
8	13	127	6	5473	699.7	7.82	0	0	36.2	2.63
8	13	127	7	1581	585.5	2.70	0	0	1630.9	2.63
8	13	128	0	1608	928.2	1.73	824	492	334.2	1.04
8	13	129	1	5494	940.9	5.84	0	0	232.3	2.25
8	13	129	2	4231	777.2	5.44	0	0	161.2	2.25
8	13	130	0	7418	1535.3	4.33	4102	2059	270.2	3.41
8	13	131	2	1859	248.4	7.48	0	0	355.6	4.40
8	13	131	3	6516	453.7	14.37	0	0	132.2	4.40
8	13	131	4	1330	186.9	7.12	0	0	79.3	4.40
8	13	131	5	4999	388.7	12.86	0	0	28.1	4.40
8	13	132	1	1486	406.1	3.66	0	0	57.6	1.95
8	13	132	2	1097	296.3	3.70	0	0	2137.9	1.95
8	13	132	4	6969	687.5	10.14	0	0	767.3	1.95
8	13	132	5	2977	703.3	4.23	0	0	65.9	1.95
8	13	132	6	4978	882.6	5.64	0	0	335.5	1.95
8	13	132	7	1692	293.3	5.77	0	0	14.0	1.95
8	13	133	2	5222	591.1	8.83	0	0	248.4	5.11
8	13	133	3	6575	590.5	11.13	0	0	241.7	5.11
8	13	133	4	3567	416.5	8.56	0	0	123.6	5.11
8	13	134	0	6269	677.5	9.25	952	1943	692.1	2.12
8	13	135	1	3217	262.9	12.24	0	0	46.6	2.87
8	13	135	2	7096	609.3	11.63	0	0	238.2	2.87
8	13	136	1	2646	337.9	7.83	0	0	482.7	3.39
8	13	137	1	3789	139.5	27.16	0	0	21.2	41.48
8	31	70	14	0	.0	9.21	0	0	.0	2.82
8	59	95	9	5231	.0	8.39	0	0	.0	2.74
8	59	120	8	5265	.0	7.01	0	0	.0	3.15
8	59	120	21	3399	.0	7.01	0	0	.0	3.15
8	13	136	2	574	.0	7.83	0	0	.0	3.39
8	13	137	2	3711	.0	27.16	0	0	.0	41.48

APPENDIX M

DENVER CO STUDY CALIBRATION RESULTS

DENVER CO STUDY
CALIBRATION RESULTS

SAMPLE START DATE	PEM ID	AVERAGE SLOPE	AVERAGE INTERCEPT	CLASS CODES SLOPE	CLASS CODES INTER.	CLASS CODES OVERALL
110182	174816	.950	.500	1	1	1
110182	174818	.961	.250	1	1	1
110182	174820	.962	.700	1	1	1
110182	174831	.949	.750	1	1	1
110182	174837	.971	.700	1	1	1
110182	179854	.967	.000	1	1	1
110182	179862	.947	.500	1	1	1
110182	179863	.956	.000	1	1	1
110182	179943	1.001	.000	1	1	1
110182	179944	.987	.100	1	1	1
110283	174799	.963	.200	2	1	2
110283	174803	.978	.300	1	1	1
110283	174808	.974	.500	1	1	1
110283	174809	.958	.400	1	1	1
110283	174811	.960	.350	2	1	2
110283	174812	.994	.300	1	1	1
110283	174827	.943	.400	3	1	3
110283	174832	.953	.200	2	1	2
110283	174835	.973	.350	1	1	1
110283	179938	.942	.850	1	1	1
110382	174816	.976	.450	1	1	1
110382	174818	.971	.100	1	1	1
110382	174820	.950	.650	1	1	1
110382	174831	.956	.750	2	1	2
110382	174837	.957	.800	1	1	1
110382	179863	.957	.000	1	1	1
110382	179943	.974	.000	1	1	1
110382	179944	.955	.950	2	3	3
110482	174799	.916	.000	2	1	2
110482	174803	.976	.600	2	1	2
110482	174808	.979	.700	2	1	2
110482	174809	.906	.500	2	1	2
110482	174811	.902	.500	2	1	2
110482	174832	.922	.150	2	1	2
110482	179854	.936	.000	2	1	2
110482	179938	.955	.350	1	1	1
110582	174820	1.010	1.000	1	1	1
110582	174821	1.006	.450	2	1	2
110582	174827	1.015	.200	6	6	6
110582	179861	.681	.250	5	1	5
110582	179862	.952	.350	1	1	1
110582	179863	.999	.300	1	1	1
110582	179943	.451	1.200	5	1	5
110582	179944	.990	.450	1	1	1
110682	174799	.909	.150	2	1	2
110682	174803	.952	.700	1	2	2
110682	174808	.937	.600	2	1	2
110682	174811	.895	.400	1	1	1
110682	174824	1.015	.000	1	1	1
110682	174830	.989	.250	1	1	1
110682	174832	.915	.200	1	1	1

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CORRECTED
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DENVER CO STUDY
CALIBRATION RESULTS

51

SAMPLE START DATE	PEM ID	AVERAGE SLOPE	AVERAGE INTERCEPT	CLASS CODES		
				SLOPE	INTER.	OVERALL
110682	179854	.920	.000	2	1	2
110982	174799	.971	.950	2	1	2
110982	174803	.927	1.750	3	4	4
110982	174808	.985	.350	2	1	2
110982	174809	.962	.850	2	2	2
110982	174811	.968	.650	2	1	2
110982	174812	.972	.900	1	3	3
110982	174820	.982	.550	1	1	1
110982	174821	.956	.550	2	2	2
110982	174822	.984	.650	1	1	1
110982	174824	.975	.950	1	2	2
111082	174830	.992	.000	1	1	1
111082	174831	.963	.900	2	1	2
111082	174835	.941	.150	3	1	3
111082	179854	.950	.200	2	1	2
111082	179861	.986	.300	1	1	1
111082	179862	.918	2.100	3	5	5
111082	179863	.960	.150	2	1	2
111082	179938	.957	.450	2	1	2
111082	179943	.976	.100	2	1	2
111082	179944	.970	.500	2	1	2
111182	174799	.969	.350	1	1	1
111182	174808	.970	.300	1	1	1
111182	174809	.950	1.300	1	1	1
111182	174811	.984	.500	1	1	1
111182	174812	.981	.050	1	1	1
111182	174816	.940	.850	2	1	2
111182	174820	.971	.950	1	1	1
111182	174821	.985	.000	1	1	1
111182	174822	.965	.300	1	1	1
111182	174824	.974	.250	1	1	1
111182	174827	.980	1.100	1	1	1
111282	174818	.934	.500	3	1	3
111282	174830	1.003	.100	1	1	1
111282	174831	.956	.800	1	1	1
111282	174835	.979	.850	1	1	1
111282	179854	.973	.000	2	1	2
111282	179861	.971	.800	1	1	1
111282	179862	.976	.800	2	1	2
111282	179863	.985	.000	1	1	1
111282	179938	.969	.600	1	1	1
111282	179943	.987	.800	1	1	1
111282	179944	.949	1.050	2	1	2
111382	174809	.972	1.500	1	1	1
111382	174811	.969	.900	1	1	1
111382	174812	.993	.300	1	1	1
111382	174816	.998	.400	1	1	1
111382	174820	.983	1.100	1	1	1
111382	174821	.989	.000	1	1	1
111382	174827	.931	1.250	2	1	2
111482	174818	.964	.500	1	1	1

DENVER CO STUDY
CALIBRATION RESULTS

SAMPLE START DATE	PEM ID	AVERAGE SLOPE	AVERAGE INTERCEPT	CLASS CODES		
				SLOPE	INTER.	OVERALL
111482	174830	.977	.750	1	1	1
111482	174831	.973	.450	1	1	1
111482	174835	.999	.400	1	1	1
111482	179862	.922	.550	3	1	3
111482	179863	.984	.100	1	1	1
111482	179944	.934	.850	2	1	2
111582	174808	.975	.550	1	2	2
111582	174811	.937	.900	1	1	1
111582	174816	1.002	.450	1	1	1
111582	174820	.956	.750	2	2	2
111582	174821	.986	.000	1	1	1
111582	174827	.978	1.200	1	1	1
111582	179861	.964	.800	1	1	1
111582	179938	.971	.200	1	1	1
111582	179943	1.003	.500	1	1	1
111682	174809	.974	.300	1	1	1
111682	174812	.955	.700	1	1	1
111682	174818	1.010	.400	1	1	1
111682	174822	.902	.000	4	1	4
111682	174824	.990	.100	1	1	1
111682	174830	.998	.000	1	1	1
111682	174831	.976	.650	1	1	1
111682	174835	1.004	.150	1	1	1
111682	179944	.978	.800	1	1	1
111782	174808	.966	.550	2	1	2
111782	174811	.891	.300	4	1	4
111782	174820	.945	1.000	2	1	2
111782	174827	.963	.650	2	1	2
111782	179943	.952	.200	2	1	2
111882	174809	.961	.900	1	1	1
111882	174822	.952	.650	2	2	2
111882	174830	.967	.250	1	1	1
111882	174831	1.001	.400	1	1	1
111882	179863	.974	.000	1	1	1
111982	174811	.972	.750	1	1	1
111982	174820	.988	.850	2	2	2
111982	174821	.982	.000	1	1	1
111982	174824	.993	.400	1	1	1
111982	174827	.947	1.100	1	1	1
111982	179861	.998	.700	6	6	6
111982	179938	.944	.400	1	1	1
111982	179943	.988	.650	2	1	2
111982	179944	.982	.700	1	1	1
112082	174809	.950	1.050	1	2	2
112082	174812	.979	.350	1	1	1
112082	174816	.947	.500	1	2	2
112082	174822	.967	.000	1	1	1
112082	174830	.983	.250	1	1	1
112082	174831	.998	.250	1	1	1
112082	174835	.939	.750	1	1	1
112082	179854	.955	.000	2	1	2

DENVER CO STUDY
CALIBRATION RESULTS

SAMPLE START DATE	PEM ID	AVERAGE SLOPE	AVERAGE INTERCEPT	CLASS CODES SLOPE	INTER.	OVERALL
112082	179863	.976	.100	1	1	1
112182	174808	.964	.950	1	1	1
112182	174811	.998	.800	1	1	1
112182	174820	.958	1.300	1	1	1
112182	174821	1.005	.000	1	1	1
112182	174824	1.001	.300	1	1	1
112182	179861	.527	.700	5	1	5
112182	179938	.982	.600	1	1	1
112182	179943	.987	.700	1	1	1
112182	179944	.961	.750	1	1	1
112282	174809	.971	.600	6	6	6
112282	174812	.985	.100	6	6	6
112282	174816	.951	.600	2	1	2
112282	174822	.990	.000	6	6	6
112282	174830	1.000	.000	6	6	6
112282	174831	.980	.300	6	6	6
112282	174835	.952	.500	1	1	1
112282	179854	.955	.000	2	1	2
112282	179863	.983	.000	6	6	6
112982	174811	.958	.200	2	1	2
112982	174816	.953	.200	1	1	1
112982	174820	.987	.450	1	1	1
112982	174821	.981	.000	6	6	6
112982	174824	.987	.000	1	1	1
112982	179938	.959	.350	1	1	1
112982	179943	.947	.350	2	1	2
113082	174799	.966	.300	1	1	1
113082	174803	.980	.150	1	1	1
113082	174808	.976	.200	1	1	1
113082	174809	.983	.100	1	1	1
113082	174818	.960	1.000	2	1	2
113082	174837	.985	.150	1	1	1
113082	179862	.976	.100	1	1	1
120182	174808	.960	1.050	1	1	1
120182	174811	.976	.950	1	1	1
120182	174816	.969	.300	1	1	1
120182	174820	1.012	.650	1	1	1
120182	174824	.987	.000	1	1	1
120182	179938	.974	.000	1	1	1
120182	179943	.954	.150	3	1	3
120282	174812	.987	.200	1	1	1
120282	174818	.999	.650	1	1	1
120282	174821	.992	.550	1	1	1
120282	174822	1.005	.300	1	1	1
120282	174827	.992	.400	1	1	1
120282	174831	1.004	.000	1	1	1
120282	179863	.998	.550	1	1	1
120382	174799	.945	.200	3	1	3
120382	174808	.935	.850	2	1	2
120382	174809	.951	.100	2	1	2
120382	174811	.958	.750	1	1	1

DENVER CO STUDY
CALIBRATION RESULTS

SAMPLE START DATE	PEM ID	AVERAGE SLOPE	AVERAGE INTERCEPT	CLASS CODES SLOPE	INTER.	OVERALL
120382	174816	.978	.100	2	1	2
120382	174820	.993	.400	1	1	1
120382	174824	.970	.000	1	1	1
120382	174837	.973	.000	1	1	1
120382	179938	.966	.000	1	1	1
120382	179943	.817	.000	5	1	5
120482	174803	.966	.300	1	1	1
120482	174812	.976	.200	1	1	1
120482	174827	.945	.400	1	1	1
120482	174830	.950	.400	2	1	2
120482	174831	.975	.000	1	1	1
120482	174835	.991	.250	1	1	1
120482	179854	.965	.000	2	1	2
120482	179861	.971	.050	1	1	1
120482	179862	.985	.000	1	1	1
120482	179944	.973	.150	1	1	1
120582	174799	.981	.300	1	1	1
120582	174809	.964	.400	1	1	1
120582	174811	.877	.150	4	1	4
120582	174816	.982	.350	1	1	1
120582	174818	.995	.650	1	1	1
120582	174821	.996	.300	1	1	1
120582	174822	.996	.100	1	1	1
120582	174824	.971	.000	1	1	1
120582	174837	.976	.150	1	1	1
120582	179863	.959	.100	2	1	2
120682	174803	.949	.000	1	1	1
120682	174812	.970	.000	1	1	1
120682	174827	.932	.250	1	1	1
120682	174830	.932	.000	2	1	2
120682	174831	.958	.250	1	1	1
120682	174835	1.022	.000	1	1	1
120682	179854	.971	.000	1	1	1
120682	179861	.955	.000	1	1	1
120682	179862	.982	.000	1	1	1
120682	179944	.961	.000	1	1	1
120782	174799	.966	1.250	1	1	1
120782	174811	.962	.150	1	1	1
120782	174816	.952	.850	3	2	3
120782	174821	.980	.650	1	1	1
120782	174821	.986	.050	1	1	1
120782	179863	.945	1.100	2	2	2
120882	174812	.970	.000	2	1	2
120882	174827	.964	.000	2	1	2
120882	174830	.955	.000	2	1	2
120882	179854	.966	.000	2	1	2
120882	179862	.983	.000	1	1	1
120882	179944	.961	.000	2	1	2
120982	174803	.968	.000	1	1	1
120982	174809	.940	.000	2	1	2
120982	174811	.934	.500	2	1	2

DENVER CO STUDY
CALIBRATION RESULTS

SAMPLE START DATE	PEM ID	AVERAGE SLOPE	AVERAGE INTERCEPT	CLASS CODES		
				SLOPE	INTER.	OVERALL
120982	174822	.924	.250	3	1	3
120982	174831	.953	.000	2	1	2
120982	174835	.965	.000	2	1	2
120982	174837	.952	.000	2	1	2
120982	179861	.960	.000	2	1	2
120982	179863	.948	.000	2	1	2
121082	174799	.978	.150	1	1	1
121082	174812	.977	.250	1	1	1
121082	174827	.982	.300	1	1	1
121082	174830	.951	.200	1	1	1
121082	179858	.987	.350	1	1	1
121082	179862	.985	.300	1	1	1
121082	179938	.960	.100	1	1	1
121082	179943	.972	.200	1	1	1
121082	179944	1.000	.200	1	1	1
121182	174803	.973	.050	1	1	1
121182	174809	.966	.000	1	1	1
121182	174811	.946	.450	2	1	2
121182	174831	.982	.000	1	1	1
121182	174835	.984	.000	1	1	1
121182	174837	.981	.000	1	1	1
121182	179854	.957	.000	2	1	2
121182	179861	.968	.450	1	1	1
121282	174799	.946	1.150	2	2	2
121282	174812	.974	.000	1	1	1
121282	174822	.976	.050	2	1	2
121282	174827	.976	.650	1	1	1
121282	174830	.949	.450	3	1	3
121282	179858	.999	.000	1	1	1
121282	179863	.946	.700	3	2	3
121282	179943	.967	.550	1	2	2
121382	174803	.953	.100	1	1	1
121382	174809	.949	.550	1	1	1
121382	174811	.961	.350	1	1	1
121382	174820	.973	.500	1	1	1
121382	174837	.978	.200	1	1	1
121382	179854	.983	.000	1	1	1
121382	179862	.973	.200	1	1	1
121482	174799	.974	.300	2	1	2
121482	174812	.975	.000	1	1	1
121482	174827	.999	.050	1	1	1
121482	174830	.933	.000	2	1	2
121482	179858	.987	.000	1	1	1
121482	179943	.968	.100	1	1	1
121582	174803	.948	.300	1	1	1
121582	174808	.981	.000	1	1	1
121582	174809	.970	.300	1	1	1
121582	174831	.990	.100	1	1	1
121582	174835	.876	.450	4	1	4
121582	174837	.950	.000	1	1	1
121582	179862	.972	.150	2	1	2

DENVER CO STUDY
CALIBRATION RESULTS

SAMPLE START DATE	PEM ID	AVERAGE SLOPE	AVERAGE INTERCEPT	CLASS CODES		
				SLOPE	INTER.	OVERALL
121582	179863	.952	.000	2	1	2
121682	174799	.949	1.050	1	1	1
121682	174812	.979	.400	1	1	1
121682	174820	.964	.550	1	1	1
121682	174821	.940	.500	2	1	2
121682	174827	.973	.750	1	1	1
121682	179854	.960	.000	2	1	2
121682	179858	.942	.000	2	1	2
121682	179943	.752	.450	5	1	5
121782	174803	1.006	.400	1	1	1
121782	174809	.988	.150	1	1	1
121782	174831	.995	.000	1	1	1
121782	179862	1.006	.000	1	1	1
121882	174799	1.017	.150	1	1	1
121882	174812	.982	.000	1	1	1
121882	174821	1.004	.000	1	1	1
121882	179858	.986	.000	1	1	1
121982	174803	.984	.400	1	1	1
121982	174809	.970	.650	2	1	2
121982	174811	.988	.450	2	1	2
121982	174830	.982	.150	1	1	1
121982	174831	.988	.250	2	1	2
121982	174837	.992	.250	1	1	1
121982	179854	.970	.100	2	1	2
121982	179862	.983	.000	2	1	2
122082	174799	.915	1.000	3	1	3
122082	174808	.955	.650	2	1	2
122082	174812	.986	.450	1	1	1
122082	174820	.965	.650	2	2	2
122082	174821	.977	.200	2	1	2
122082	174827	.986	.300	1	1	1
122082	179863	.988	.350	2	1	2
122082	179943	.970	.300	2	1	2
122182	174824	.996	.250	1	1	1
122182	174832	1.004	.100	1	1	1
122182	174944	.982	.000	2	1	2
122282	174812	.974	.550	1	1	1
122282	179854	.984	.000	1	1	1
122282	179863	.982	.350	1	1	1
010583	174799	.973	.400	2	1	2
010583	174803	.916	.250	4	1	4
010583	174808	.969	.200	2	1	2
010583	174809	.942	.800	3	1	3
010583	174812	.981	.200	1	1	1
010583	174816	.908	.900	4	1	4
010583	174831	.959	1.100	1	1	1
010583	174837	.973	.000	1	1	1
010583	179854	1.013	.100	6	6	6
010583	179862	.991	.000	2	1	2
010583	179863	.966	.100	2	1	2
010583	179943	.945	.050	2	1	2

DENVER CO STUDY
CALIBRATION RESULTS

SAMPLE START DATE	PEM ID	AVERAGE SLOPE	AVERAGE INTERCEPT	CLASS CODES SLOPE	CLASS CODES INTER.	CLASS CODES OVERALL
010683	174811	.958	.000	2	1	2
010683	174818	.951	.600	1	1	1
010683	174820	.965	.600	1	2	2
010683	174821	.925	.350	3	1	3
010683	174822	.947	.550	2	2	2
010683	174824	.943	.650	2	1	2
010683	174827	.987	.100	2	1	2
010683	174830	.949	.450	2	1	2
010683	174832	.962	.450	2	1	2
010683	179861	.982	.450	1	1	1
010683	179938	.958	.400	2	1	2
010683	179944	.990	.100	1	1	1
010783	174799	.938	1.000	2	1	2
010783	174808	.963	.350	2	1	2
010783	174809	.967	.050	2	1	2
010783	174816	.947	.350	2	1	2
010783	179854	.946	.200	2	1	2
010783	179858	.970	.000	2	1	2
010783	179862	1.009	.050	1	1	1
010783	179943	1.011	.450	1	1	1
010883	174811	.984	.400	1	1	1
010883	174820	1.000	.450	1	1	1
010883	174822	.991	.400	1	1	1
010883	174824	.994	.450	1	1	1
010883	174830	.961	.300	3	1	3
010883	174832	.982	.300	1	1	1
010883	179944	.977	.200	1	1	1
010983	174799	.994	.450	1	1	1
010983	174803	1.013	.250	2	1	2
010983	174808	.980	1.100	2	2	2
010983	174809	.956	.950	2	2	2
010983	174816	.987	.400	1	1	1
010983	174821	.972	.150	2	1	2
010983	174827	1.001	.450	1	1	1
010983	174938	.971	.950	1	1	1
010983	179854	.975	.400	1	1	1
010983	179943	.990	.700	6	6	6
011083	174812	.985	.000	1	1	1
011083	174818	1.004	.200	1	1	1
011083	174820	.998	.300	1	1	1
011083	174822	.991	.400	1	1	1
011083	174824	.970	.400	1	1	1
011083	174831	.916	.000	3	1	3
011083	174832	.977	.050	1	1	1
011083	179862	1.119	.000	3	1	3
011083	179863	.987	.000	6	6	6
011083	179944	.998	.300	1	1	1
011183	174799	.960	.300	2	1	2
011183	174803	.977	1.400	1	4	4
011183	174808	.962	.250	1	1	1
011183	174809	1.002	.250	2	1	2

DENVER CO STUDY
CALIBRATION RESULTS

SAMPLE START DATE	PEM ID	AVERAGE SLOPE	AVERAGE INTERCEPT	CLASS CODES		
				SLOPE	INTER.	OVERALL
011183	174811	.988	.250	1	1	1
011183	174816	.983	.250	1	1	1
011183	174821	.984	.250	1	1	1
011183	174827	.976	.300	1	1	1
011183	174837	1.012	.000	1	1	1
011183	179854	.970	.550	1	1	1
011183	179938	.978	.750	1	1	1
011283	174812	.972	.300	2	1	2
011283	174818	.951	.500	2	2	2
011283	174820	.957	.450	3	1	3
011283	174822	.938	.600	3	1	3
011283	174831	.911	.300	4	1	4
011283	174832	.957	.550	2	1	2
011283	179858	.953	.000	2	1	2
011283	179861	.954	.400	2	1	2
011283	179862	.974	.000	2	1	2
011283	179443	.987	.400	1	1	1
011283	179944	.963	.350	2	1	2
011383	174799	.940	.500	3	1	3
011383	174803	.957	1.400	2	2	2
011383	174808	.982	.250	2	1	2
011383	174811	1.004	.200	1	1	1
011383	174816	.997	.400	1	1	1
011383	174824	.988	.200	1	1	1
011383	174827	.988	.400	1	1	1
011383	174830	1.021	.200	6	6	6
011383	174837	.980	.000	1	1	1
011383	179854	.990	.100	1	1	1
011383	179938	.979	.200	1	1	1
011483	174812	.966	.000	2	1	2
011483	174818	.956	.050	2	1	2
011483	174820	.944	.250	2	1	2
011483	174822	.966	.400	2	1	2
011483	174832	.993	.400	6	6	6
011483	179858	.977	.300	1	1	1
011483	179861	.943	.700	2	1	2
011483	179862	.987	.300	2	1	2
011483	179944	.979	.000	1	1	1
011583	174799	1.006	.650	1	1	1
011583	174808	.945	.650	1	1	1
011583	174811	.943	.350	2	1	2
011583	174816	.918	.800	2	1	2
011583	174821	.977	.450	1	1	1
011583	174824	.945	.550	1	1	1
011583	174837	.981	.050	1	1	1
011583	179854	.956	.200	2	1	2
011583	179863	.962	.150	2	1	2
011583	179938	.972	.300	2	1	2
011683	174803	1.001	.100	1	1	1
011683	174812	.984	.400	1	1	1
011683	174818	.969	.450	1	1	1

DENVER CO STUDY
CALIBRATION RESULTS

				CLASS CODES		
SAMPLE START DATE	PEM ID	AVERAGE SLOPE	AVERAGE INTERCEPT	SLOPE	INTER.	OVERALL
011683	174820	.956	.500	2	1	2
011683	174822	.970	.200	1	1	1
011683	174827	.973	.700	1	1	1
011683	179858	.976	.350	1	1	1
011683	179861	.971	.700	1	1	1
011683	179862	.979	.100	1	1	1
011683	179944	.978	.000	1	1	1
011783	174808	.940	.750	2	1	2
011783	174811	.978	.150	1	1	1
011783	174816	.959	.800	2	1	2
011783	174821	.996	.150	1	1	1
011783	174824	.986	.800	1	1	1
011783	174831	.999	.050	1	1	1
011783	174832	.987	.350	1	1	1
011783	174837	.990	.000	2	1	2
011783	179854	.991	.050	1	1	1
011783	179938	.996	.150	1	1	1
011783	179943	.974	.250	2	1	2
011883	174799	.943	.600	2	1	2
011883	174812	.986	.150	1	1	1
011883	174818	.967	.300	2	1	2
011883	174820	.978	.100	1	1	1
011883	174822	.964	.300	2	1	2
011883	174827	.971	.200	2	1	2
011883	179858	.966	.000	2	1	2
011883	179861	.992	.250	1	1	1
011883	179862	.981	.300	2	1	2
011883	179944	.956	.350	3	1	3
011983	174811	1.001	.300	1	1	1
011983	174816	.995	.850	1	1	1
011983	174824	.989	.800	1	1	1
011983	174831	.986	.350	1	1	1
011983	174832	.962	1.000	2	2	2
011983	179854	1.004	.150	1	1	1
011983	179938	.974	.200	2	1	2
011983	179943	1.001	.450	1	1	1
012083	174809	.977	.200	2	1	2
012083	174812	1.005	.050	1	1	1
012083	174818	.960	.400	3	1	3
012083	174820	1.023	.400	6	6	6
012083	174821	1.000	.100	1	1	1
012083	174835	.988	.000	2	1	2
012083	179862	1.007	.000	1	1	1
012083	179944	1.007	.000	1	1	1
012183	174811	.960	.550	2	1	2
012183	174816	.992	.250	1	1	1
012183	174824	.988	.150	1	1	1
012183	174831	.962	.000	2	1	2
012183	174832	.996	.050	1	1	1
012183	179854	.976	.100	2	1	2
012183	179863	.988	.700	6	6	6

DENVER CO STUDY
CALIBRATION RESULTS

SAMPLE START DATE	PEM ID	AVERAGE SLOPE	AVERAGE INTERCEPT	CLASS CODES SLOPE	CLASS CODES INTER.	CLASS CODES OVERALL
012183	179938	.990	.000	1	1	1
012283	174809	.972	.200	1	1	1
012283	174812	.967	.000	1	1	1
012283	174818	.964	.550	2	1	2
012283	174821	.948	.250	2	1	2
012283	174835	.960	.050	2	1	2
012283	179862	.984	.100	1	1	1
012283	179943	.964	.150	1	1	1
012283	179944	.989	.100	1	1	1
012383	174799	.969	.700	1	1	1
012383	174803	1.005	.150	1	1	1
012383	174811	1.091	.750	4	2	4
012383	174816	1.073	.400	4	1	4
012383	174831	1.047	.000	2	1	2
012383	174832	1.011	.000	1	1	1
012383	174837	.989	.000	1	1	1
012383	179854	.991	.000	1	1	1
012383	179863	.991	.000	1	1	1
012383	179938	.991	.250	1	1	1
012483	174809	.970	.250	1	1	1
012483	174812	.995	.000	2	1	2
012483	174818	.979	.450	2	1	2
012483	174820	.996	.450	1	1	1
012483	174824	.978	1.050	2	1	2
012483	174835	1.000	.050	1	1	1
012483	179858	.983	.000	2	1	2
012483	179862	1.016	.000	1	1	1
012483	179943	1.006	.050	1	1	1
012483	179944	1.011	.050	1	1	1
012583	174799	.954	.300	2	1	2
012583	174803	.970	.150	2	1	2
012583	174808	.985	.250	1	1	1
012583	174811	.959	.250	1	1	1
012583	174816	.915	.550	1	1	1
012583	174821	.939	.250	2	1	2
012583	174822	.947	.950	2	1	2
012583	174831	.958	.250	2	1	2
012583	174837	.959	.200	2	1	2
012583	179854	.934	.350	2	1	2
012583	179863	.995	.300	6	6	6
012583	179938	.944	.200	2	1	2
012683	174809	1.009	.750	1	1	1
012683	174812	.932	1.100	3	2	3
012683	174818	.962	.500	1	1	1
012683	174820	.788	.250	5	1	5
012683	174824	.945	.750	2	1	2
012683	174832	.948	.750	2	3	3
012683	174835	.948	.000	2	1	2
012683	179858	.975	.000	1	1	1
012683	179861	.928	.700	2	1	2
012683	179862	.964	.350	2	1	2

DENVER CO STUDY
CALIBRATION RESULTS

SAMPLE START DATE	PEM ID	AVERAGE SLOPE	AVERAGE INTERCEPT	CLASS CODES SLOPE	CLASS CODES INTER.	CLASS CODES OVERALL
012683	179943	.983	.400	1	1	1
012683	179944	.984	.200	1	1	1
012783	174799	.986	.000	1	1	1
012783	174803	.986	.200	1	1	1
012783	174811	.999	.250	1	1	1
012783	174816	.972	.600	2	1	2
012783	174821	.990	.000	1	1	1
012783	174822	.994	.400	1	1	1
012783	174827	1.005	.150	1	1	1
012783	174831	.988	.000	2	1	2
012783	174837	.988	.000	1	1	1
012783	179854	.981	.450	1	1	1
012783	179938	.972	.350	1	1	1
012883	174808	.971	.200	2	1	2
012883	174809	.961	.600	2	1	2
012883	174812	.994	.100	1	1	1
012883	174818	.983	.200	1	1	1
012883	174824	.964	.650	1	1	1
012883	174832	.960	.500	2	2	2
012883	174835	.995	.200	2	1	2
012883	179858	.971	.100	2	1	2
012883	179862	.991	.100	1	1	1
012883	179943	.961	.150	1	1	1
012883	179944	.997	.100	6	6	6
012983	174811	.973	.200	1	1	1
012983	174821	.970	.000	2	1	2
012983	174827	.981	.100	3	1	3
012983	174831	1.003	.000	1	1	1
012983	174837	.991	.100	1	1	1
012983	179854	.988	.100	1	1	1
012983	179938	1.003	.100	1	1	1
013083	174808	.982	.600	1	1	1
013083	174812	1.021	.050	1	1	1
013083	174820	1.017	.150	1	1	1
013083	174824	.987	.400	1	1	1
013083	174832	1.009	.450	1	1	1
013083	179861	1.016	.350	1	1	1
013083	179943	1.017	.050	1	1	1
013183	174811	.968	.250	1	1	1
013183	174816	.961	.100	2	1	2
013183	174821	.986	.000	1	1	1
013183	174822	.963	.600	2	1	2
013183	174827	.982	.000	1	1	1
013183	174830	.996	.200	1	1	1
013183	174831	.975	.350	1	1	1
013183	174837	.970	.750	1	1	1
013183	179854	.960	.400	2	1	2
013183	179862	.985	.050	1	1	1
013183	179938	.954	.300	2	1	2
020183	174799	.946	.500	2	1	2
020183	174808	.979	.450	1	1	1

DENVER CO STUDY
CALIBRATION RESULTS

SAMPLE START DATE	PEM ID	AVERAGE SLOPE	AVERAGE INTERCEPT	CLASS CODES		
				SLOPE	INTER.	OVERALL
020183	174809	.985	.150	1	1	1
020183	174812	.996	.000	1	1	1
020183	174818	.953	.550	2	1	2
020183	174824	.992	.500	1	1	1
020183	174832	.969	.100	1	1	1
020183	179858	.948	.000	2	1	2
020183	179861	.968	.600	1	1	1
020183	179943	.991	.100	2	1	2
020183	179944	.962	.000	2	1	2
020283	174821	1.028	.150	2	1	2
020283	174803	1.005	.300	1	1	1
020283	174811	.985	.250	1	1	1
020283	174822	.968	.750	1	1	1
020283	174830	1.004	.100	1	1	1
020283	174831	.992	.000	1	1	1
020283	174835	.992	.050	1	1	1
020283	174837	1.001	.550	1	1	1
020283	179827	1.009	.050	1	1	1
020283	179854	.982	.500	1	1	1
020283	179862	1.004	.050	1	1	1
020283	179863	1.011	.200	1	1	1
020383	174799	.953	.250	2	1	2
020383	174808	.980	.350	1	1	1
020383	174809	.979	.150	1	1	1
020383	174812	.980	.100	1	1	1
020383	174818	.980	.150	1	1	1
020383	174820	.955	.200	2	1	2
020383	174824	.989	.300	1	1	1
020383	174832	.962	.250	2	1	2
020383	179858	.991	.150	1	1	1
020383	179943	.957	.350	1	1	1
020383	179944	.963	.550	1	2	2
020483	174803	.991	.450	1	1	1
020483	174821	.955	.250	2	1	2
020483	174822	.994	.350	1	1	1
020483	174830	.975	.500	2	1	2
020483	174831	.957	.250	3	1	3
020483	174835	.980	.350	2	1	2
020483	174837	.955	.250	2	1	2
020483	179854	.961	.250	2	1	2
020483	179862	.973	.250	2	1	2
020483	179863	.978	.250	2	1	2
020583	174799	.967	.350	1	1	1
020583	174808	.946	.650	2	1	2
020583	174809	.955	.500	2	1	2
020583	174816	.948	.300	2	1	2
020583	174818	.995	.100	1	1	1
020583	174820	.978	.800	1	1	1
020583	174824	.953	.550	2	1	2
020583	179858	.992	.200	1	1	1
020583	179938	.961	.300	2	1	2

DENVER CO STUDY
CALIBRATION RESULTS

SAMPLE START DATE	PEM ID	AVERAGE SLOPE	AVERAGE INTERCEPT	CLASS CODES SLOPE	INTER.	OVERALL
020583	179944	.968	.050	2	1	2
020683	174803	1.004	.300	1	1	1
020683	174822	.905	.700	4	1	4
020683	174831	.988	.350	1	1	1
020683	179854	.941	.250	3	1	3
020683	179862	1.000	.000	6	6	6
020783	174799	.923	1.200	3	1	3
020783	174808	.956	1.100	2	1	2
020783	174816	.943	.350	3	1	3
020783	174818	.937	.800	3	2	3
020783	179938	.961	.150	2	1	2
020883	174821	.974	.000	2	1	2
020883	174824	.967	.450	1	1	1
020883	174830	.946	.300	3	1	3
020883	174831	.972	.650	1	1	1
020883	174832	.962	.000	2	1	2
020883	174837	.981	.250	1	1	1
020883	179854	.944	.250	3	1	3
020883	179858	.963	.250	1	1	1
020883	179863	.926	.100	4	1	4
020883	179944	.957	.300	2	1	2
020983	174799	.710	.150	5	1	5
020983	174803	.955	.350	2	1	2
020983	174808	.996	.400	1	1	1
020983	174809	.987	.350	1	1	1
020983	174811	.981	.500	1	1	1
020983	174812	.949	.200	2	1	2
020983	174827	.993	.150	1	1	1
020983	174835	.959	.000	2	1	2
020983	179938	.966	.700	1	2	2
020983	179943	.999	.450	1	1	1
021083	174820	.968	.150	2	1	2
021083	174830	.975	.100	1	1	1
021083	174831	.985	.000	1	1	1
021083	174832	.978	.000	1	1	1
021083	174837	.979	.050	1	1	1
021083	179854	.973	.600	1	1	1
021083	179858	.979	.150	1	1	1
021083	179863	.976	.300	1	1	1
021083	179944	.956	.000	2	1	2
021183	174799	.940	.650	2	1	2
021183	174809	.944	.300	2	1	2
021183	174812	.987	.300	1	1	1
021183	174816	.875	1.050	4	1	4
021183	174824	.974	.250	2	1	2
021183	174836	.953	.450	2	1	2
021183	179704	.947	.200	2	1	2
021183	179861	.942	.300	2	1	2
021183	179943	.952	.350	1	1	1
021283	174803	.975	.700	1	2	2
021283	174811	.954	.650	2	1	2

DENVER CO STUDY
CALIBRATION RESULTS

SAMPLE START DATE	PEM ID	AVERAGE SLOPE	AVERAGE INTERCEPT	CLASS CODES		
				SLOPE	INTER.	OVERALL
021283	174820	.950	.050	2	1	2
021283	174827	.965	.200	2	1	2
021283	174830	1.017	.000	6	6	6
021283	174831	.847	.000	5	1	5
021283	174832	.974	.050	2	1	2
021283	174835	.971	.000	2	1	2
021283	174837	.960	.000	2	1	2
021283	179854	.954	.300	2	1	2
021283	179858	.981	.100	1	1	1
021283	179863	.990	.000	1	1	1
021283	179944	1.017	.450	1	1	1
021383	174799	.948	.400	2	1	2
021383	174808	.992	.250	1	1	1
021383	174809	.643	.450	5	1	5
021383	174812	.980	.100	1	1	1
021383	174816	.973	.350	1	1	1
021383	174818	.957	.500	2	1	2
021383	174824	.977	.700	1	1	1
021383	174836	.975	.150	1	1	1
021383	174960	1.008	.200	1	1	1
021383	179704	.984	1.050	1	3	3
021383	179783	.945	.700	2	1	2
021383	179938	.955	.250	2	1	2
021383	179950	.963	.500	2	1	2
021483	174803	.970	.400	1	1	1
021483	174811	.963	.100	1	1	1
021483	174827	.966	.250	1	1	1
021483	174830	.982	.050	1	1	1
021483	174831	.929	.000	3	1	3
021483	174832	.931	.000	3	1	3
021483	174835	1.037	.050	1	1	1
021483	179854	.963	.950	1	1	1
021483	179858	.983	.050	1	1	1
021483	179861	.970	.200	1	1	1
021483	179863	.991	.050	1	1	1
021483	179944	.954	.650	1	1	1
021583	174808	.975	.300	1	1	1
021583	174809	.967	.350	1	1	1
021583	174812	.972	.000	1	1	1
021583	174816	.960	.500	1	1	1
021583	174818	.972	.300	2	1	2
021583	174824	.979	.200	1	1	1
021583	174836	.942	.200	2	1	2
021583	174960	.949	.650	2	1	2
021583	179704	.992	.650	1	1	1
021583	179783	.931	.750	3	1	3
021583	179938	.968	.350	1	1	1
021683	174799	.953	.550	2	2	2
021683	174803	.993	.100	1	1	1
021683	174811	.936	.400	2	1	2
021683	174820	.955	.550	2	1	2

DENVER CO STUDY
CALIBRATION RESULTS

SAMPLE START DATE	PEM ID	AVERAGE SLOPE	AVERAGE INTERCEPT	CLASS CODES		
				SLOPE	INTER.	OVERALL
021683	174827	.968	.200	2	1	2
021683	174830	.968	.150	1	1	1
021683	174831	.954	.250	2	1	2
021683	174832	.976	.350	2	1	2
021683	174835	.935	.550	3	2	3
021683	179861	.956	.600	2	1	2
021683	179862	.972	.600	2	1	2
021683	179863	.955	.100	2	1	2
021683	179944	.942	.800	2	1	2
021783	174808	.973	.850	1	1	1
021783	174809	.959	.200	2	1	2
021783	174812	.992	.000	1	1	1
021783	174816	.970	.200	1	1	1
021783	174818	.956	.600	3	2	3
021783	174821	.948	1.350	3	4	4
021783	174824	.973	.200	2	1	2
021783	174836	.963	.200	2	1	2
021783	174837	.948	.450	2	1	2
021783	179783	.953	.500	2	1	2
021783	179854	.979	.000	1	1	1
021783	179938	.969	.000	2	1	2
021783	179943	.944	.550	2	1	2
021883	174803	.972	.850	1	1	1
021883	174811	.996	.250	1	1	1
021883	174820	.948	.150	2	1	2
021883	174830	.975	.150	1	1	1
021883	174831	.939	.150	3	1	3
021883	179862	.939	.400	2	1	2
021883	179863	.985	.150	1	1	1
021883	179944	.961	.200	2	1	2
021883	179950	.972	.350	2	1	2
021983	174808	.551	.300	5	1	5
021983	174809	.972	.400	1	1	1
021983	174818	1.020	.400	1	1	1
021983	174821	.959	.100	2	1	2
021983	174824	1.011	.500	1	1	1
021983	174832	1.011	.300	1	1	1
021983	174960	.994	.150	1	1	1
021983	179858	.993	.050	1	1	1
021983	179954	1.001	.050	1	1	1
022083	174816	.952	.550	1	1	1
022083	174820	.972	.300	1	1	1
022083	174822	1.004	.000	1	1	1
022083	174830	.991	.000	1	1	1
022083	179831	.955	.550	2	1	2
022083	179861	.982	.700	1	1	1
022083	179862	.987	.850	1	1	1
022083	179863	.960	.250	2	1	2
022083	179943	.993	.100	1	1	1
022083	179944	.968	.000	2	1	2
022083	179950	.970	.750	1	1	1

DENVER CO STUDY
CALIBRATION RESULTS

SAMPLE START DATE	PEM ID	AVERAGE SLOPE	AVERAGE INTERCEPT	CLASS CODES		
				SLOPE	INTER.	OVERALL
022183	174799	.926	1.150	2	1	2
022183	174803	.968	.350	1	1	1
022183	174812	.968	.000	1	1	1
022183	174818	.962	.300	1	1	1
022183	174827	.955	1.050	1	1	1
022183	174835	.972	.100	1	1	1
022183	174836	.929	.550	2	1	2
022183	179704	.908	.400	3	1	3
022183	179854	.970	.300	1	1	1
022183	179938	.999	.050	1	1	1
022183	179954	.948	.250	3	1	3
022283	174809	.972	.400	1	1	1
022283	174816	.976	.350	1	1	1
022283	174820	.953	.150	2	1	2
022283	174822	1.011	.400	1	1	1
022283	174824	.966	.550	1	1	1
022283	174830	.994	.250	1	1	1
022283	174837	.983	.000	1	1	1
022283	174960	1.053	.200	2	1	2
022283	179858	.982	.000	1	1	1
022283	179861	.989	.250	1	1	1
022283	179862	.957	.000	2	1	2
022283	179943	.974	.500	1	1	1
022283	179944	.961	.100	1	1	1
022383	174803	.937	.200	3	1	3
022383	174811	.948	.400	2	1	2
022383	174818	.970	.400	1	1	1
022383	174827	.985	.350	1	1	1
022383	174830	1.017	.250	1	1	1
022383	174831	.922	.800	3	1	3
022383	174832	.969	.200	1	1	1
022383	174835	.954	.250	2	1	2
022383	179783	.966	.100	1	1	1
022383	174812	.993	.200	1	1	1
022383	179854	.983	.450	1	1	1
022383	179938	.930	.750	2	1	2
022383	179954	.942	.300	2	1	2
022483	174809	.955	.650	2	1	2
022483	174816	.944	.500	2	1	2
022483	174820	.981	.500	6	6	6
022483	174822	.943	1.000	2	1	2
022483	174830	.968	.500	1	1	1
022483	174837	.967	1.100	1	2	2
022483	174960	.965	.650	1	1	1
022483	179861	.981	.500	1	1	1
022483	179863	.968	.550	1	1	1
022483	179944	.875	.300	4	1	4
022483	179950	.969	.700	1	1	1
022583	174803	.966	.200	2	1	2
022583	174811	.955	.550	1	1	1
022583	174812	.961	.150	1	1	1

DENVER CO STUDY
CALIBRATION RESULTS

SAMPLE START DATE	PEM ID	AVERAGE SLOPE	AVERAGE INTERCEPT	CLASS CODES SLOPE	INTER.	OVERALL
022583	174818	.941	.650	2	1	2
022583	174827	.948	.250	2	1	2
022583	174831	.934	.750	2	1	2
022583	174832	.988	.100	2	1	2
022583	174835	.962	.500	2	1	2
022583	179783	.963	.150	2	1	2
022583	179854	.942	.550	2	1	2
022583	179954	.948	.300	2	1	2
022683	174808	.985	.350	1	1	1
022683	174809	.968	.150	1	1	1
022683	174816	.970	.100	1	1	1
022683	174822	.996	.250	1	1	1
022683	174824	.968	.150	1	1	1
022683	174830	1.027	.000	1	1	1
022683	174837	.983	.000	1	1	1
022683	174960	.985	.200	2	1	2
022683	179861	1.009	.100	6	6	6
022683	179862	.989	.450	1	1	1
022683	179863	.992	.150	1	1	1
022683	179943	.989	.150	1	1	1
022783	174803	.970	.200	1	1	1
022783	174811	.983	.400	1	1	1
022783	174812	.972	.100	6	6	6
022783	174818	.939	.350	2	1	2
022783	174821	.970	.600	1	1	1
022783	174832	.988	.000	1	1	1
022783	174835	.974	.100	1	1	1
022783	174836	.979	.250	1	1	1
022783	179858	.987	.300	1	1	1
022783	179938	.947	.400	1	1	1
022783	179950	.955	1.500	2	3	3
022783	179954	.970	.350	1	1	1

APPENDIX N

PEM MALFUNCTIONS

A log maintained on each PEM listed all instances during the Denver study in which the PEM failed a zero-span check, all other instrument failures that occurred (whether or not data were affected), and any other situations in which nonroutine servicing was performed. Table N-1 lists all malfunctions recorded in these logs. Each malfunction is assigned to one of six general categories. Of the 157 malfunctions listed in the table, 33 involved failed zero-span checks or excessive zero-span drift, 14 involved problems with the pump batteries, 55 were traced to the pump itself, 16 involved the battery supply for the Magus unit, 39 appeared to be related to the internal operation of the Magus unit, and 52 were traced to other causes. The 11 PEM malfunctions that occurred most frequently are discussed below.

Clogged Pump Caused Low Flow Rate

Figure N-1 shows a simplified schematic of the PEM sampling interface. The sample is pulled through a vertical scrubber column and a series of foam rubber filters by the sample pump, and is then pushed through the GE sensor cell. Flow problems begin with the vertical intake of the scrubber column. The scrubber medium (i.e., the potassium permanganate) turns from purple to brown as it becomes depleted and begins to physically break down. This creates fine particles, which are intercepted by the foam filter at the bottom of the scrubber column. These particles may eventually pass through the column filter entering the pump vacuum line. From there, the particles may pass through the vacuum line filters, enter the pump, and cause the pump to become clogged and the pump flow to decrease.

Initially pump flow problems were corrected by increasing the supply voltage to the pump motor. This remedy proved to be only temporarily effective, as particles continued to clog the pump and the additional current drain on the pump battery drastically decreased battery life. A series of preventive maintenance steps were found to be more effective in reducing PEM flow problems. On an "as needed" basis, each PEM's pump was disassembled to clean the head assembly and inspect its three diaphragms. A can of compressed air was used to blow-clean each component of the head assembly and its respective jets. In addition, the scrubber medium was removed from the scrubber column and strained through a fine mesh screen. Each foam filter in the sample interface was also removed and cleaned, as was the pump vacuum line. These steps helped to reduce pump flow problems, but did not eliminate them completely.

PEDCo's experience with the pump system suggests that a redesign is needed before this system is used in future studies. A suggested improvement requiring no additional components and entailing minimum additional cost is

TABLE N-1. PEM MALFUNCTIONS

PEM ID	Date	Malfunction classification					
		Zero-span	Pump batteries	Pump	MAGUS battery	MAGUS	Other
174799	11-1-82			a			
	11-4-82	b					
	11-6-82	b					
	11-13-82	c					
	12-14-82						d
	12-21-82	b					
	1-17-83						e
	1-19-83				f		
174803	12-13-82						g
	1-5-83	b					
	1-16-83	c					
	1-24-83				f		
	2-7-83		f				
	2-10-83					h	
	2-12-83		f				
	2-17-83					i	
	2-19-83			j			
	2-24-83					i	
174808	11-2-82					k	
	11-21-82						e
	11-29-82						l
	12-1-82						g
	12-9-82						l
	1-31-83					i	
174809	11-4-82	b					
	11-22-82						e
	1-26-83			m			
174811	11-4-82	b					
	11-6-82	b					
	11-17-82	b					
	11-29-82				l		
	12-1-82			m			
	12-5-82	b					
	12-7-82						e,n
	1-6-83					i	
	1-20-83					i	
	2-6-83			m			
	2-25-83			m			

(continued)

TABLE N-1 (continued)

		Malfunction classification					
PEM ID	Date	Zero-span	Pump batteries	Pump	MAGUS battery	MAGUS	Other
174812	11-22-82						e,o
	12-5-82			m			
	12-20-82					i	
174816	11-2-82			m			n
	11-3-82					i	
	12-1-82			m		i	
	12-15-82			m			
	1-5-83	b					
	2-6-83			m			
	2-12-83	b					
	2-19-83			m			
174818	11-12-82					i	
	11-15-82						p
	12-3-82			j			
	12-4-82			m			
	12-7-82						l
	1-21-83						d
	2-4-83					i	
	2-6-83	b					
	2-21-83			j			
174820	11-21-82	b					e
	11-29-82						l
	12-1-82			m			
	12-3-82					i	
	12-9-82						o
	12-20-82						e
	1-21-83					k	
	1-22-83			m			
	1-26-83			m			
	1-27-83			a			
	2-20-83			m			
	2-24-83					k	
174821	11-18-82			m			
	11-20-82						q
	11-29-82					i	
	12-1-82			m			
	12-9-82				l		
	1-6-83	b				i	

(continued)

TABLE N-1 (continued)

		Malfunction classification					
PEM ID	Date	Zero-span	Pump batteries	Pump	MAGUS battery	MAGUS	Other
174822	11-10-82			m			
	11-12-82			m			
	11-16-82	b					
	11-22-82						e,o
	12-9-82	b					
	12-12-82	b					
	12-14-82			m			r
	2-4-83			a			
	2-26-83					i	
174824	12-1-82						g
174827	11-5-82	b					
	11-21-82						e
	1-20-83					k	
	2-14-83						n
174830	11-20-82			m			
	11-22-82						g
	12-19-82						e
	1-10-83			m		h	
	1-14-83					k	
	1-16-83					i	
	2-12-83						d
	2-21-83					i	
	2-26-83			m			
174831	11-20-82	b					
	11-21-82			m			
	11-22-82				f		
	2-5-83					i	
	2-9-83			m			
	2-12-83						e
	2-15-83	b					
	2-20-83			m			
	2-22-83	b		s			
174832	11-1-82			j			
	11-18-82			m			
	11-30-82						e
	1-15-83					k	
	1-18-83						g
	2-15-83	b					
	2-24-83					t	

(continued)

TABLE N-1 (continued)

PEM ID	Date	Malfunction classification					
		Zero-span	Pump batteries	Pump	MAGUS battery	MAGUS	Other
174835	11-10-82	b					
	11-13-82			m			
	11-15-82		f				
	11-22-82						e
	12-15-82	b					
	1-29-83		f				
	2-17-83			j			
174836	2-21-83			m			
	2-25-83			a			
174837	11-3-82					i	
	11-13-82			m			
174960	2-9-83		f	m			
179704	2-9-83		f	m			
179783	2-9-83				f		u
179854	11-6-82	b					
	11-22-82						e
	12-4-82						n
	1-5-83						e
	1-21-83						e
179858	12-21-82				f		
179861	11-5-82	b					
	11-12-82			m			
	11-19-82				f		
	12-6-82						e
	1-15-83					i	
	1-31-83					v	
	2-6-83			m			
179862	11-14-82	b					
	1-7-83					i	
	1-22-83						d
	2-7-83	b					
	2-14-83						d,n
	2-20-83			m			

(continued)

TABLE N-1 (continued)

PEM ID	Date	Malfunction classification					
		Zero-span	Pump batteries	Pump	MAGUS battery	MAGUS	Other
179863	11-14-82					i	
	11-22-82		f				
	1-8-83					v	
	1-11-83				f		
	1-16-83				f		
	1-18-83				f		
	1-24-83					w	
	1-26-83						e
	2-6-83			m			
	2-19-83						g
	2-24-83		f				
	2-26-83			m			
179938	11-4-82					i	
	11-21-82					i	
	12-1-82						g
	12-10-82						e
	12-?-82		f				
	2-20-83			m			
	2-21-83			a			
179943	11-3-82		f				
	11-13-82		f				
	12-1-82					i	
	12-3-82	b					
	12-16-82						e
	12-20-82		f		f		
	1-10-83						e
	1-14-83				f		
	1-25-83					v	
	1-29-83		f				
	1-31-83				f		
	2-12-83						e
	2-21-83				f		
179944	11-14-82			m			
	1-15-83					i	
	1-17-83				f		
	1-29-83					v	
	2-24-83	b					

(continued)

TABLE N-1 (continued)

PEM ID	Date	Malfunction classification					
		Zero-span	Pump batteries	Pump	MAGUS battery	MAGUS	Other
179950	2-9-83			m			
	2-17-83		f				
	2-19-83			s			
	2-21-83	b		s			
179954	2-9-83			m			x
	2-21-83			m			

[a] Defective or damaged part.

[b] Failed zero-span.

[c] Excessive zero and/or span drift.

[d] Loose Amphenol plug.

[e] No change in time displayed and no data stored ("lock up").

[f] Low battery voltage or battery dead.

[g] Known or suspected programming error.

[h] Switched to unspecified mode.

[i] Switched to ALOG mode.

[j] Pump stopped, cause not specified.

[k] Switched to SCLR mode.

[l] Broken bias battery strap.

[m] Clogged pump caused low flow rate.

[n] Bad solder joint.

[o] Unspecified problem in bias battery.

[p] Loose connection on recorder jack.

[q] PEM times out of sync. during data transfer.

[r] Faulty activity button.

[s] Unspecified pump problem.

[t] Clock stopped and then restarted.

[u] Missing intake adaptor.

[v] Switched to DONE mode.

[w] Display went blank.

[x] Jumper cut when unit received.

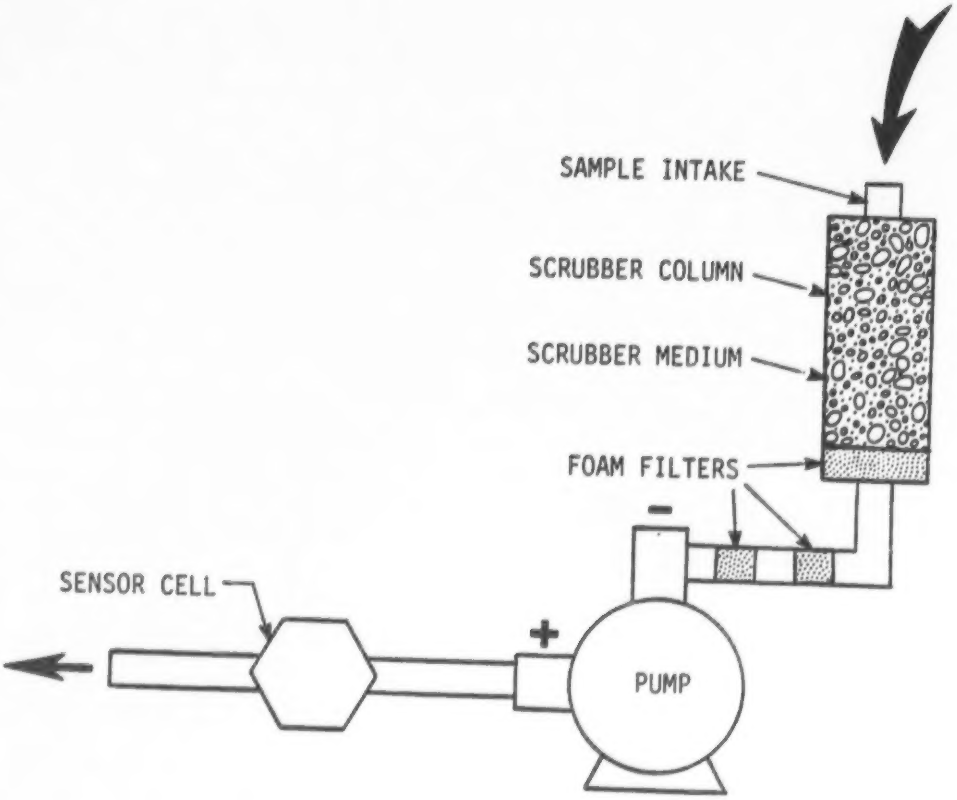
SAMPLE INTAKE
SCRUBBER COLUMN
SCRUBBER MEDIUM
FOAM FILTERS
−
SENSOR CELL
+
PUMP

Figure N-1. Simplified schematic of PEM sampling interface.

to change the configuration of the scrubber column by inverting it. Because of the low flow requirements of the PEM, the fine particles from the scrubber medium would settle out at the intake side of the column. This would improve the effectiveness of the foam filters and eliminate virtually all flow-related problems at the source.

PEM Failed Zero-span

The principal causes of the frequent failures of PEM's to pass post zero-span checks are rather difficult to determine. PEDCo's experience suggests that many of the failures may have been temperature-related. A direct comparison of failure frequency during cold weather sampling vs. failure frequency during warm weather sampling should be performed to test this hypothesis. Another possible cause may be rough handling of the PEM during the sample period. Because subjects are naturally reluctant to report instances in which the PEM was dropped or abused, it may be difficult to investigate this hypothesis. It should be emphasized that even stationary monitors occasionally fail zero-span checks, even when operated under laboratory conditions.

PEM Switched to ALOG Mode

Occasionally a PEM would switch into the ALOG mode during a sample period. Data stored in the Magus data subsystem usually remained in the memory until the PEM switched modes. If the ALOG mode was in the "yes" position when the switch occurred, the Magus unit would store hourly average CO values. If the ALOG mode was in the "no" position, no data were stored. This problem may have been caused by a defect in the Magus system's read-only memory (ROM) logic. Whatever the cause, it should be isolated and corrected before this system is used in the future.

Lock-up

When a PEM "locked up," the liquid crystal display (LCD) display and Magus data subsystem stopped working, the LCD time did not advance, and the Magus data subsystem would not log CO data. In approximately 50 percent of the cases, all stored data in the Magus memory registers were lost; in the remaining 50 percent, all data up to the time the PEM locked up were retrievable. The lockup problem was correctable in virtually all cases. The PEM was first put on charge, since in many cases the Magus battery pack voltage level had dropped below acceptable levels. Once the voltage was brought up to an acceptable level, the PEM would unlock itself. If the PEM remained locked up, the cause was usually found to be a defective Magus power supply. Over the course of the study, approximately 10 PEM's were returned to the Magus Group for installation of new power supplies.

Low Pump Battery Voltage

As discussed above, the procedure initially used to correct low pump flow was to increase the pump motors supply voltage. Optimum pump motor voltage was 1.8 VDC. Increasing the supply voltage to 2.2 VDC or greater significantly decreased the life of the pump battery pack. Battery life fell from approximately 24 hours to 16 to 20 hours, depending on actual pump motor supply voltage. Deterioration of the pump batteries with use was another cause of low pump battery voltage. During the latter part of field operations, individual batteries in the pump battery pack deteriorated to the point where they would accept a charge but not maintain voltage levels. When this occurred, the battery was discharged completely and charged fully. If the battery still would not hold a charge, it was discarded and replaced with a new one.

Low Magus Battery Voltage

Low Magus battery voltage was usually caused by deterioration of the battery with age. During the latter part of the field operations, single batteries in the Magus battery pack deteriorated to the point that they would accept a charge but not maintain voltage levels. This problem was handled by the same procedure described above for low pump battery voltage.

Known or Suspected Programming Error

In all cases of known programming errors, a field operator did not initialize the LOG or SCLR modes during the programming procedure. The result was either a data set containing only hourly data or the loss of all data. A serious deficiency in the Magus data subsystem logic is that once the PEM has been programmed, there is no way to verify that it was done properly.

PEM Switched to SCLR Mode

This malfunction is similar to that described above as "PEM Switched to ALOG Mode" and the same comments apply.

Broken Bias Battery Straps

The mechanism used for strapping bias batteries to the Magus digital and analog circuit boards had a basic design flaw. This problem was recognized immediately, and the PEM's were returned to the California headquarters of Magus where they were repaired.

Loose Amphenol Plug

Another basic design flaw was discovered in the output plug from the GE sensor cell board. The original plug was a male, nonlocking Hewlett Packard (HP) plug that did not match the female Amphenol receptor plug at the input of the Magus data subsystem. Over the course of the first few weeks of field operations, PEDCo replaced each male HP plug with the proper male Amphenol plug. This plug is an interlocking type that mates with the female Amphenol receptor plug. These replacements eliminated all loose plug problems.

Bad Solder Joint

Over the course of field operation, a number of solder joints broke loose (e.g., battery connectors, LCD wires). In all cases, the broken joints were repairable and caused no major problems.